

T H E S I S

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by EVAN H. FRASER,

M.B., C.M. (First Class Honours)

F.R.C.S., Ed.

Heriot Research Fellow, Edinburgh University.


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An EXPERIMENTAL RESEARCH into the RELATIONS and CONNECTIONS of CERTAIN NERVE TRACTS and NUCLEI in the MEDULLA and PONS, especially those of the POSTERIOR LONGITUDINAL BUNDLE and DEITERS' NUCLEUS.

Of the longitudinally directed fibres in Pons and Medulla probably none have excited more interest and research than those which are grouped together under the name of Posterior Longitudinal Bundle (Fasciculus Longitudinalis Medialis). This strand is relatively a short one being only traceable as a distinct bundle between the limits of the upper Pons and lower Medulla, but its constituent fibres pass on and reach, and have relations, to, very distant parts of the Central Nervous System.

The Posterior Longitudinal Bundle is well known to the comparative anatomist being found as a distinct tract not only in all Mammals but also in the Reptiles and Fishes; indeed much recent work on this fasciculus has been done on these lower forms, in which it attains a relatively larger size than in the higher types (Foster)²⁴. It is of interest in this relation to note that in the development of the human nervous system this bundle is one of the earliest to obtain its sheath of myelin, which



appears around its fibres about the 4th month.

The anatomical relationships of the Posterior Longitudinal Bundle while it exists as a distinct strand, may be summed up in a few words :- in the Medulla it appears as a definite rounded bundle of fibres (large and small) situated immediately below the floor of the Fourth Ventricle, just external to the middle line. It is separated from the floor of the Ventricle in its lower part by the Hypoglossal Nucleus, while a little further forwards the Nucleus of the Sixth Nerve and the Genu of the Facial Nerve intervene between it and the floor. About this level the shape of the strand changes and it becomes somewhat oval or pyriform in outline, and still maintaining this shape, passes on into the tegmental part of Pons and Mid Brain. It is less defined now, especially as regards its external limits. In this more anterior part of its course the bundle lies in immediate relation to the inferior aspect of the Grey Matter which surrounds the Aqueduct of Sylvius. As the Fasciculus passes on through the Mid Brain it begins to be tilted somewhat upwards at its outer end, and approximates by its lower and inner end to its fellow of the opposite side, so that the two bundles together form a sort of trench

which is occupied by the masses of Nerve Cells which constitute the Nuclei of origin of the Fourth and Third Cranial Nerves. At the lower level of the Motor Oculi Nucleus the Posterior Longitudinal Bundle is still a large and definite tract, but as it courses past this great collection of cells, it very rapidly loses its compact structure and becomes so reduced in bulk and so broken up that its further course is very difficult to follow; indeed it may be said to enter here a sort of terra incognita where definite knowledge as to its course and relations gives place very largely to conjecture; such widely different terminations for its fibres as the Cerebral Cortex on the one hand and the Nucleus of the Posterior Commissure on the other having been suggested at different periods by such authorities as Meynert and Kölliker respectively. With regard to the relations of this bundle if followed towards the Spinal Cord, there is less divergence of opinion, almost all observers being now agreed that its fibres are in connection with the Antero-Lateral Columns of the Spinal Cord, but the nature of this relationship is still in dispute. The researches of Obersteiner and Kölliker lead them to regard the fibres as arising in the Cord and ascending through the Antero-Lateral Columns to join the Posterior

Longitudinal Bundle; while Van Gehuchten and Held look on the tract as a descending one, carrying fibres from a higher level downwards into the Cord; the former describe an increase in size of the bundle as traced from below upwards, the latter observers claim that this increase is to be noted in following the tract from above downwards.

As might be expected from this divergence of opinion as to the source and termination of the fibres forming the Posterior Longitudinal Bundle, there is also much clashing of statement as to the functions which these fibres serve. Cajal and Kölliker look on the bundle as Sensory carrying afferent impulses towards the Brain, while Van Gehuchten and Held describe it as Motor conveying efferent impulses towards the Cord. Enough has been said to show that widely divergent opinions are still held with regard both to the anatomy and physiology of this strand of fibres; its extent, relationships and functions being all alike somewhat uncertain. For this reason it was felt that in spite of the large amount of work already done in relation to this tract there was still room for further efforts to clear up, if possible, some of the doubt surrounding this bundle, and with this hope in view this research was entered upon.

Before passing to the consideration of work done personally, a short historical review of previous researches in this relation may be of value.

In 1877 Forel^{13.} described the Posterior Longitudinal Bundle and traced it into relationship with the Third Cranial Nerve, which he notes as breaking up the constituent fibres of the bundle in emerging. No very definite termination for the bundle is described, but it is suggested that fibres pass from it either to the Third Nerve or the Third Nucleus, or to the Raphe at this level.

In 1880 Duval and Laborde¹⁷ published a most exhaustive paper dealing with the Posterior Longitudinal Bundle (*La Bandelette longitudinale posterieure de la Calotte*) in relation to Motor Cranial Nerves. They state definitely that fibres pass from one Posterior Longitudinal Bundle into the roots of the opposite Third and Fourth Nerves, and they derive these fibres from the Sixth Nucleus. They figure a small detached bundle of fibres lying internal to the Posterior Longitudinal Bundle (from which it is derived) by means of which the fibres pass to the Fourth Nerve, while those entering the Third Nerve roots come from the more internal strands of the Posterior Longitudinal Bundle as it lies ventral to the Nucleus of this nerve and pass out directly in its trunk.

^{59.}
Schwalbe (1881) in describing the Posterior Longitudinal Bundle refers to Meynert's views with regard to its ending in relation to the Lenticular Nucleus, or even its passage as high as the Cerebral Cortex, but himself inclines to regard it as a Commissural Tract uniting the Motor Cranial Nerves (XII, VI, IV and III).

^{61.}
Spitzka in 1885 and again in 1888 strongly opposes the view advanced by Meynert as to the relation of the Posterior Longitudinal Bundle to the Cerebral Cortex, and points out in support of his contention that in Reptiles and Amphibians, in which the Fore Brain is but little developed, the Posterior Longitudinal Bundle is large; he associates this bundle for origin with the Anterior Corpora Quadrigemina which in these cases are very large. He regards, then, this bundle as the path by which the Anterior Corpora Quadrigemina are related to the Nuclei of Eye Muscle Nerves. In addition to these fibres Spitzka also recognises connecting strands between the Third and Sixth Nuclei as passing in this bundle.

^{35.}
Knoll (1886) describes movements of the eyes as a result of stimulating the floor of the Fourth Ventricle below the level of the Sixth Nucleus similar to those produced by acting on the Anterior

Corpora Quadrigemina. This he ascribes to the stimulation of the fibres of the Posterior Longitudinal Bundle.

^{15.}
Darkschewitsch (1886) describes a connection between the Posterior Longitudinal Bundle and the Posterior Commissure into which he directly traces fibres passing from the bundle. Other fibres of this bundle he traces to an ending in a Nucleus of small cells situated anterior to the Third Nucleus which he names "oberer Oculomotoriuskern" but which is now generally known as "Darkschewitsch's Nucleus".

^{44.}
Marchi (1886) after the removal of one-half of the Cerebellum in dogs and monkeys obtained a widespread degeneration, many fibres being traceable through the Middle Cerebellar Peduncles into the Posterior Longitudinal Bundle and Fillet, chiefly of the same side. In these tracts the degeneration passes up as far as the Corpora Quadrigemina and down into the Antero-Lateral Columns of the Cord. Marchi also describes an extensive degeneration of Cranial Motor Nerves which he ascribes to the passage to these of degenerated fibres from the Posterior Longitudinal Bundle.

^{34.}
Jakowenko in 1888 describes a case in which he found secondary degeneration of the Posterior Longitudinal Bundle as the result of scattered areas

of softening in the Mid Brain. He comes to the conclusion that the fibres which Darkschewitsch traced to the Posterior Commissure are not to be found in the lower part of the Posterior Longitudinal Bundle. He asserts that this strand contains (a) short (or commissural) and (b) long fibres, the latter showing specially an ascending degeneration and so may be regarded as sensory. They come to the bundle from the Spinal Cord.

^{28.} Gudden (1889) states that the Mole "in which there is neither Oculo-Motor Nucleus nor Nerve" has as large a Posterior Longitudinal Bundle as the Rabbit. This, he thinks, disproves any relationship between the Third Nucleus and the bundle, at least as regards the origin of fibres.

^{38.} Koppen (1889) attacks the problem of the relationships of Posterior Longitudinal Bundle in the Lizard. Here the bundle can be traced as a distinct tract throughout the whole length of the Cord, lying between the Central Canal and the Ventral Commissure; also in the Medulla, Pons, and Mid Brain it is closely associated with the central Grey Matter, especially that of the VI, IV and III Nerves. In passing up through the Medulla, Koppen describes the bundle as giving off fibres to the

Nuclei of the Auditory Nerve, and also to the Cerebellum. Koppen also notes a great diminution in the size of the Posterior Longitudinal Bundle about the level of the Third Nucleus; he supports Darkschewitsch in stating that some of its fibres pass directly to the Posterior Commissure and cross in this to the opposite side of the brain.

In 1890 Mingazzini,⁴¹ working by Marchi's method, after the removal of one-half of the Cerebellum, traces fibres passing through the Middle Peduncle to be associated with the Third, Fourth and Sixth Nuclei by means of the Posterior Longitudinal Bundle.

Obersteiner⁵⁰ (1890) regards the Posterior Longitudinal Bundle as built up of successive series of short fibres which beginning in the Cord connect Motor Nuclei of different levels up as far as those of the Eye Muscle Nerves. He follows Duval and Laborde in describing fibres passing from the Sixth Nucleus through the Posterior Longitudinal Bundle directly into the nerve roots of the Third Nerve. His view then is, that the Posterior Longitudinal Bundle has a purely Commissural function.

In 1891 Kölliker³⁶ noted the existence of Collaterals rising from the fibres of the Posterior Longitudinal Bundle in its course through the

Medulla and Pons but did not definitely trace these.

Tooth and Turner⁶⁶ (1891), making use of Weigert's method of staining in a case of Bulbar Paralysis, state that they can trace fibres into the Facial Nerve Trunk from the Nuclei of the Twelfth and Sixth Nerves, passing by way of the Posterior Longitudinal Bundle. They also state that the Third Nucleus gives fibres which join the Facial Trunk at the Genu and pass out with it, and they come to the conclusion that muscles around the eye and mouth are to some extent under the influence of the Third, Sixth and Twelfth Nuclei, so that, according to this view, the Posterior Longitudinal Bundle is not merely commissural for the Eye Muscle Nuclei but also conveys fibres between other Cranial Motor Nuclei and Nerves.

In 1892 Kölliker⁷² in his description of the origin of the Third Nerve in man definitely separates Darkschewitsch's Nucleus from those proper to the Third Nerve, stating that no fibres pass from it into the Third Nerve roots. In it, he says, end the fibres of the Posterior Longitudinal Bundle, and from it pass the fibres of the Posterior Commissure; that is to say, there is an indirect connection but no continuity between the bundle and the commissure. He suggests for this collection of Nerve Cells the

name "tiefen ^eKern der hintern ^ACommissur" (i.e. deep Nucleus of Posterior Commissure).

³⁰Held (1892), working at the connections of the Antero-Lateral tracts of the Cord with Mid and Hind Brain in Cats and Rats, describes the Posterior Longitudinal Bundle as the most anterior prolongation of the Ground Bundles of these tracts. These fibres find their termination in the Nerve Cells of the Formatio-Reticularis, and especially in a Nucleus of large cells named by Flechsig "Oberer Lateralkern". In addition to these fibres Held states that the Posterior Longitudinal Bundle also contains association fibres for the Nuclei of the Eye Muscle Nerves.

³¹In 1893 the same author continuing this line of research notes the ending in the Anterior Corpora Quadrigemina of many fibres from the Central Auditory and Optic paths.. These end around cells whose axis cylinder processes sweep down around the Central Grey Matter of the Aqueduct to form the "Fontaineartige Haubenkreuzung" and curving downwards pass into the Posterior Longitudinal Bundle. From this descending strand Collaterals pass to the Third, Fourth and Sixth Nuclei. The continuation of these fibres is traceable right down into the Spinal Cord, where they take part in

the formation of the Ground Bundles of the Antero-Lateral Tracts. So in this work Held takes up the view that the Posterior Longitudinal Bundle is largely composed of descending fibres from the Grey Matter of Anterior Corpora Quadrigemina, from the upper Lateral Nucleus, and from the Nucleus of Posterior Commissure, these fibres passing into relation to Cranial and Spinal Motor Nuclei, and so presumably putting these to some extent under the control of higher centres.

Bruce¹¹ (1892) suggests as probable, although yet requiring proof, that the Posterior Longitudinal Bundle conveys fibres to the Facial Nerve from the Twelfth Nucleus below and the Third Nucleus above, so as to relate Oral and Orbital Muscles of expression, especially to these two Nuclei.

Kölliker³⁷ in 1893 expresses views greatly in contrast with the statements of Held given above. He describes the Posterior Longitudinal Bundle definitely as an ascending sensory tract, having for its function the conveying of impulses from Spinal and Cranial Sensory Nerves to the Nuclei of the Eye Muscle Nerves. He notes again the presence of Collaterals derived from this tract passing to the Nuclei of III, IV, VI and XII, and describes a diminution in size of the bundle from the level of the

Fourth Nucleus upwards to Darkschewitsch's Nucleus in which the ultimate ending of these fibres occurs and which he reaffirms intervenes between them and the Posterior Commissure to which they do not directly pass.

^{18.}
Edinger (1893) inclines to the view that the Posterior Longitudinal Bundle does more than merely unite Eye Muscle Nuclei, and states that it is also the bond of union for other Cranial Nerves. In a 9th month foetus he was unable to trace any of its fibres further forwards than the Third Nucleus, and indeed figures the bundle as terminating here, but seems to hint at a continuation more anteriorly to a collection of cells which he describes as lying lateral to the Grey Matter round the Aqueduct of Sylvius which he names Superior Nucleus of the Posterior Longitudinal Bundle. He states that this Nucleus exists in all animals. Edinger also draws attention to the rapid increase in size of the Posterior Longitudinal Bundle as it descends past the Third Nucleus. This he ascribes to the numerous fibres passing between the Nucleus and the bundle. Although he does not give a definite statement as to whether he regards the Posterior Longitudinal Bundle as an ascending or descending tract, the use

of the term "endigung des hintern Längsbundel im Oculomotoriuskern" makes it appear as though he regarded it as afferent in nature.

^{3.} Bechterew (1894) makes an important addition to our knowledge of the Posterior Longitudinal Bundle. He confirms the view that there are two sorts of fibres contained in this system, long in relation to the Ground Bundles of the Cord; short or commissural in relation especially to Eye Muscle Nuclei. He shows that the latter develop later, are smaller in size, and lie more laterally in the upper course of the bundle. Anteriorly he describes the Posterior Longitudinal Bundle as being continuous with the ventral part of the Posterior Commissure. Bechterew like Held notes the relation of fibres from Meynert's decussation to the Posterior Longitudinal Bundle so that really this strand is a collection of at least three kinds of fibres, those passing between different Motor Nuclei; those ascending from Anterior Ground Bundles of the Cord; and those descending from the region of the Anterior Corpora Quadrigemina.

^{14.} Cramer (1894) has conducted a research with regard to this bundle working on the human foetus. He comes to the conclusion that it represents the

upward continuation of the more dorsal (Posterior) part of the Anterior Ground Bundle. It is more or less clearly marked off from the surrounding strands at the level of the decussation of the Fillet, and runs forward through the whole length of Mid Brain, keeping a close relationship to the Grey Matter of this region. It is traceable as a distinct bundle as far as the level of the Third Nucleus. Here it becomes greatly diminished in size, but can still be followed to an ending in a collection of cells lying ventero-lateral to the anterior part of the Aqueduct, just where this is opening out into the Third Ventricle. During its upward course Cramer describes fibres reinforcing the bundle from the Nuclei of VII, VI, IV, and III Nerves. Cramer identifies his terminal Nucleus as that named by Darkschewitsch "Oberer Oculomotorius-kern"; by Kölliker deep Nucleus of Posterior Commissure; and by Edinger Superior Nucleus of Posterior Longitudinal Bundle.

Boyce⁹ (1895) working on cats and making use of Marchi's method of staining, shows degeneration of Posterior Longitudinal Bundle fibres after a lesion of Mid Brain passing between Anterior and Posterior Corpora Quadrigemina. This degeneration is small

in amount, and affected chiefly the smaller fibres of the bundle. This degeneration was traceable downwards in the Posterior Longitudinal Bundle of the injured side, while other fibres passing through Meynert's Decussation were seen to cross to the opposite side and form a distinct bundle, ventral to the Posterior Longitudinal Bundle, and could be traced downwards into the Cord as a separate tract. With regard to the Posterior Longitudinal Bundle itself, Boyce says that the changing position of the degeneration in this as it is followed down is sufficient to indicate a reinforcement of the bundle by entering fibres at lower levels. It is noteworthy that the lesion here cut the Posterior Longitudinal Bundle below the level of the Third Nucleus and therefore also below the so-called Superior Nucleus of the Posterior Longitudinal Bundle, and yet there is only a slight descending degeneration. Boyce points out that the position occupied by the degenerated fibres in the Posterior Longitudinal Bundle in his higher sections is such that they would lie immediately subjacent to the Third Nucleus if followed further forwards. He would appear therefore to suggest this Nucleus as their origin.

Mahaim⁴³ (1895) gives the results of a very interesting investigation, conducted by Gudden's

method. He removed the Third and Fourth Nerves from the right orbit of a one-day old rabbit, and after four months killed the animal and examined the Brain and Cord stained with Gerlach's carmine. He found marked atrophy of the right Posterior Longitudinal Bundle from the level of the Third Nucleus downwards. Not only this, but the atrophy affected a sharply localised portion of the bundle, "all the more lateral and most of the more ventral fibres being wanting." At the level of the lower end of the Fourth Nucleus the right Posterior Longitudinal Bundle was only about one-half the size of the left. Mahaim comes to the conclusion then that the Posterior Longitudinal Bundle is a very complex strand, consisting firstly, of, fibres which are not connected with Eye Muscle Nuclei, and secondly, of fibres which are so connected; the first group persist, the second group atrophy in this case. He traces these laterally placed fibres outwards in the *Formatio Reticularis*, and says that they lose themselves in relation to the Fifth Nucleus. It is interesting to compare this statement with that of Bechterew quoted above with regard to the later myelination of the smaller laterally placed fibres of the Posterior Longitudinal Bundle.

53.

Risen Russell (1895), after the removal of one

lateral lobe of the Cerebellum in dogs, applied Marchi's method of staining to the study of the resulting degenerations. As regards the changes in the Middle Peduncle his results do not confirm those of Marchi himself or of Mingazzini; he traces the degenerated fibres across the middle line of the Pons to an ending in the Grey Matter of the opposite side, a few only terminating in that of the same side. He got no degeneration in either Fillet or Posterior Longitudinal Bundle, such as the two former observers had stated to occur. After section of the Inferior Peduncle, Russell describes some scattered fibres degenerating in the Antero-Lateral columns of the Cord. These were only to be seen in the Cervical region and had disappeared in the Dorsal part of the Cord. They did not constitute a true tract, being quite irregularly arranged.

^{49.}
Mott (1895), writing on the afferent tracts in the monkey, describes one of his cases in which an extensive lesion "involving Deiters' Nucleus and other Cranial Nuclei, amongst them the Sixth," was followed by degeneration passing down into the Cord on the same side as the lesion and up towards the Brain on the opposite side. The Cord degeneration

was found in the Anterior columns as far down as the Lumbar region, and showed fibres crossing over in the Anterior Commissure to reach the opposite Anterior Horn. The ascending degeneration occupied mainly the Posterior Longitudinal Bundle of the opposite side to the lesion, and was traceable as far forwards as the Third Nucleus. Mott ascribes this ascending degeneration to the injury of the Sixth Nucleus, while he relates the descending part to the implication of Deiters' Nucleus. He agrees with Ferrier and Turner that the descending degeneration does not come directly from the Cerebellum as Marchi has stated. - He sums up by saying that probably the more anterior fibres may be Ground fibres from Cranial Motor Nuclei, particularly Ocular Nuclei, and may serve as bridges between Spinal and Cranial Nerve Cells in co-ordinated reflex movements directed by vision ; while those derived from Deiters' Nucleus convey impulses connected with equilibration down to the Anterior Horn Cells of the Spinal Cord.

Van Gehuchten²⁷ (1895), believing that the study of the more simple system of Fishes might throw light on the more complex arrangements in Mammals, worked at the Posterior Longitudinal Bundle in the Trout. He used Golgi's method of silver impregnation, examining the Fish at all stages of development

from one to thirty days. He comes to very definite conclusions about the Posterior Longitudinal Bundle, stating emphatically that it is a strand formed exclusively of descending fibres, and therefore to be regarded as Motor in function. The source of the more anterior part of the Posterior Longitudinal Bundle is, according to Van Gehuchten to be found in a collection of cells which he names Nucleus of Posterior Longitudinal Bundle lying a short distance anterior to the Third Nucleus. As the bundle descends it is reinforced by entering fibres from various Motor Nuclei. In its course the Fasciculus constantly gives off Collaterals which terminate by ramifying amongst the cells of the III, IV and VII Cranial Nuclei. The bundle can be followed down into the Cord as a distinct tract lying between "the Ventral and Accessory Commissures." While in this position it gives off fibres to the Anterior Horn, and is reinforced by fibres which enter it from cells situated in this part, these fibres being directed downwards in the bundle. Most of the fibres of the bundle are stated to be direct; that is, to descend on the same side as that on which their cells of origin lie, but some few cross to the opposite side. Van

Gehuchten then dissents absolutely from K  lliker's views with regard to the function of the Posterior Longitudinal Bundle.

^{58.} Schwabe (1896), operating on Rabbits with the view of determining the functions of the various groups of cells which constitute the Third Nucleus, arrives at results which contradict the views previously advanced by Mendel, and Tooth and Turner, that the Facial Nerve receives fibres from the Third Nucleus destined for the Muscles around the Eye. Schwabe cut the Facial Nerve, and by the use of Nissl's method, localised degenerated nerve cells only in the Facial Nucleus, no change resulting in any part of the Third Nucleus such as would have occurred had fibres derived from these cells been divided. So that apparently if fibres pass along the Posterior Longitudinal Bundle from the Third Nucleus towards the Seventh they do not enter this Nerve Trunk but end in the Nucleus.

^{22.} Flechsig (1896) in his work on the Conduction of Sensory Impulses, refers to the Optic Thalamus as a special way-station on the Sensory Path and describes as ending in it (along with the Fillet) a part of the Posterior Longitudinal Bundle, this occurring especially in relation to the Lateral Nucleus of the Thalamus.

^{12.}
 Ramon y Cajal (1896), working with Golgi's method describes many fibres arising from Deiters' Nucleus and running inwards to cross the middle line to enter the opposite Posterior Longitudinal Bundle. In this they turn some up and others down, or in some cases divide and give ascending and descending branches.

^{62.}
 Teljatnik (1897) describes a degeneration as occurring in the Posterior Longitudinal Bundle after a lesion of the Superior Vermis of the Cerebellum. He traces this forwards to end in the region of the Third Nucleus and backwards into the Cord where wide-spread degeneration of the Antero-Lateral columns is met with.

³³
 Hoche (1897), making use of both Marchi's and Weigert's methods of staining in a case of Bulbo-Spinal Paralysis in man found in addition to a degeneration in the Motor tracts a change in the Posterior Longitudinal Bundle. He states that the degeneration in this becomes more marked as one passes distalwards; in the plane of the Third Nucleus comparatively few degenerated fibres were to be seen, but at the level of the Seventh Nucleus he counts over 150 altered fibres, and this number is again increased on passing the Hypoglossal Nucleus. There is then a successive increase in amount of

degeneration as one descends. This degeneration joins below with that in the Antero-Lateral columns. Hoche then does not trace a definite relationship for the Posterior Longitudinal Bundle to the Third and Fourth Nuclei but rather to the Seventh and Twelfth; but he admits that it is difficult in this case to speak about the direction of the black streaks passing between the bundle and the various Nuclei.

Risen Russell⁵⁴ (1897) in his research on the tracts of the Medulla, refers to the changes produced in the Posterior Longitudinal Bundle by the removal of Deiters' Nucleus. He finds that this lesion produces both ascending and descending degeneration in the bundle. The descending degeneration affects the two bundles equally, so that they can be traced into the anterior columns of the Cord where in the Cervical region they form two equal areas of scattered degeneration, one on each side of Anterior Median Fissure. On the side of the lesion this tract becomes obscured in the upper Cervical Cord by the presence of another strand also degenerated which mingles with it. The descending degeneration can only be followed with certainty into the upper parts of the Thoracic Cord;

throughout its course Collaterals are furnished to the Anterior Horn of its own side, there is no evidence of any decussating fibres passing through the Anterior Commissure. Of the degenerated fibres which ascend in the Posterior Longitudinal Bundle Russell speaks less definitely, merely stating that the degeneration can be followed forward to the region of the Corpora Quadrigemina.

Gee and Tooth²⁵ (1898) describe an interesting case of a woman dying as the result of a haemorrhage into the Pons. The case was one which lent itself to the Marchi method, the patient living sixteen days after the onset of the attack, so the Brain and Cord were treated in this way. The lesion was of course extensive, destroying the Fourth and Sixth Nuclei of the right side and all the tissues intervening between these. It also slightly affected the left side. As a result of this injury both Posterior Longitudinal Bundles were found degenerated, the right bundle having been completely cut and the left somewhat damaged. Following the Posterior Longitudinal Bundles towards the Cord both showed degeneration, but this is greater on the right side. The bundles end by joining the Anterior Ground Bundles, of which they appear to form

a large part. In the Medulla the Sixth and Twelfth Nuclei show fine degeneration. Passing towards the brain the right bundle again shows greater degeneration. Fibres can be traced into the Fourth Nucleus and some are said to occur in the Nerve Trunk itself; the Third Nucleus also is pervaded with degenerating fibres. Degeneration can still be followed anterior to the Third Nucleus, but its ending is indefinite, the Corpora Mammillaria, the red Nucleus and the Optic Thalamus are all suggested as receiving these ultimate fibres. Gee and Tooth also note the presence of degenerated fibres in the Third Nerve Trunk which they ascribe to a direct passage of fibres from the Posterior Longitudinal Bundle into the roots of this nerve.

^{41.} Long (1898) describes a similar effort to trace the course of the Posterior Longitudinal Bundle fibres in man. The case was one of a Glio-Sarcoma of the Pons which had involved the entire lateral half of this. Of the resulting wide-spread degeneration that belonging to the Posterior Longitudinal Bundle system could not be followed into the Cord at all, but was distinctly traceable into the Fourth and Third Cranial Nuclei.

^{68.} Tschermak (1898) describes the degeneration of the Posterior Longitudinal Bundle as met with in a

series of experiments on cats. He states that its fibres arise from the commissural group of cells in the Anterior Horn of the Spinal Cord and pass up in the Anterior Column of the opposite side having crossed at once. As soon as the upward continuation of the Anterior and Lateral Columns reaches the level where the central canal of the Cord opens out into the Fourth Ventricle, it divides into two parts, a medio-dorsal and a ventro-lateral. The tract under consideration forms the medio-dorsal part, and gets the name of Posterior Longitudinal Bundle. In the upward continuation of this bundle Collaterals are furnished at frequent intervals to the XII, VI, IV and III Nuclei, and also to the lower, middle and upper central and lateral Nuclei; while yet others pass medially to cross in the Raphe and go to *Formatio Reticularis* of the opposite side. The longer fibres of the Posterior Longitudinal Bundle reaching the level of the Anterior Corpora Quadrigemina turn outwards and upwards between Darkschewitsch's Nucleus and the upper Lateral Nucleus to reach the Optic Thalamus; but yet other fibres are directed into and through the ventral portion of Posterior Commissure to reach similar parts on the opposite side. This arrangement then gives rise to a deep crossed connection between Spinal Cord Cells on the one hand and Cranial Motor Nuclei and Cells of *Formatio Reticularis*

as far forward as the Posterior Commissure on the other hand. Tschermak also points out that both the crossed and uncrossed Spino-Cerebellar systems (i.e. the fibres passing from the Posterior Column Nuclei to the Cerebellum) are connected by Collaterals to the Vestibular Nerve Nuclei, especially to Deiters' Nucleus, and, as Held has shown, a descending tract passes from this Nucleus through the Anterior Columns to have relation to Anterior Horn Cells, so from this it follows that a further reflex may in this way be established.

^{64.} Thomas (1898) describes the results he obtained after an experimental lesion of the Posterior Longitudinal Bundle in a dog. The bundle was cut in the floor of the Fourth Ventricle by a section made at the level of the entrance of the Restiform Body into the Cerebellum. The animal was killed fifteen days later and the Brain and Cord were treated by Marchi's method. On examination the Posterior Longitudinal Bundle was found completely divided on the one side, and slightly injured on the other; also an accidental haemorrhage had caused damage to the Formatio Reticularis just in front of the Sixth Nucleus. On tracing the Posterior Longitudinal Bundles downwards a degeneration is found in these, and also in the Formatio

Reticularis. This degeneration tends to approach the middle line as it passes down, and also tends to become more ventral in position. At the level of the pyramidal decussation the degenerated fibres reach the surface of the Cord and lie chiefly in the angle between Anterior Median Fissure and the margin of the Cord, although the posterior part of Anterior Ground Bundle contains a few granular bodies. This degeneration can be followed into the Dorsal and Lumbar parts of the Cord, spreading more laterally as it goes, but (this is noteworthy) not reaching as far back as Crossed Pyramidal Tract. Degenerated fibres could be traced to the Anterior Horn and also in the Medulla to the Twelfth Nucleus and perhaps, but not certainly, to the Tenth. On the opposite side a similar but much less marked degeneration occurred. The origin of these fibres could not be determined, but some at least come from Deiters' Nucleus. Tracing the degeneration forwards, that is, above the lesion, it was found to be bilateral but more marked on the side opposite the lesion. It could be followed as far as the Third Nucleus, many crossing fibres are seen between the two bundles. Thomas concludes by saying that the share the Posterior Longitudinal Bundle takes in the formation of the Anterior Ground Bundles

of the Cord and the relations of its fibres to the Anterior Horn Cells should draw attention to its functional importance.

Van Biervliet⁵ (1899) arrives at the conclusion that the Third Nucleus only receives fibres from the Posterior Longitudinal Bundle, and does not give any to it. His results depend on a series of experiments on Rabbits in which he removed the complete orbital contents with the effect of producing Chromatolysis in practically all the cells of the Third Nucleus. He states that not more than a dozen cells in the whole chain of his serial sections through this Nucleus fail to show this degenerative change, so that only this trivial number were left to give fibres elsewhere than to the orbital contents.

Bechterew³ (1899) again states that the Posterior Longitudinal Bundle consists of ascending fibres from the Cord and Commissural fibres for the Third, Fourth and Sixth Nuclei, and possibly for those of other Cranial Nerves as well. He also states that in its lower part the Posterior Longitudinal Bundle contains fibres passing out of the Restiform Body. He traces the bundles forwards to the Third Nucleus and describes the fibres as ending here in relation to the "Hauptkern" of this nerve and possibly also

to its accessory Nuclei. That part of the Posterior Longitudinal Bundle which does not end in the Third Nucleus passes gradually more and more Dorsal alongside of the central Grey Matter which surrounds the Aqueduct and ends ultimately in the Nucleus of the Posterior Commissure. Bechterew says that the evidence gained by the study of the myelination of fibres is enough to disprove the view of Meynert that the Posterior Longitudinal Bundle formed a continuous tract to the Cortex. He also draws attention to the rapid increase in size of the Posterior Longitudinal Bundle as it is followed downwards from the anterior extremity of the Third Nucleus. This he ascribes to the passage of fibres from it to the Nucleus to form a "Faserfilz" around the Ganglionic Cells which constitute this.

Van Gehuchten²⁶ (1900) reaffirms the descending (Motor) character of the Posterior Longitudinal Bundle, but does not accept Held's view that its fibres arise in the Anterior Corpora Quadrigemina. He quotes Pawlow's experiments in support of his view, stating here that destruction of Anterior Corpora Quadrigemina was never followed by degeneration in the Posterior Longitudinal Bundle. These fibres owe their origin according to Gehuchten to the before-mentioned Nucleus situated anterior and

lateral to the Third Nucleus. But Gehuchten has slightly modified his views since 1895, and now admits that some fibres ascend in the Posterior Longitudinal Bundle, so that he no longer claims it as purely Motor, but admits that it must be regarded as a mixed Sensori-Motor tract.

Barker¹ (1900) admits that the relations of the Posterior Longitudinal Bundle to the Ground Bundles of anterior and lateral tracts of the Cord is certain; so also is the connection between the various Eye Muscle Nuclei and the bundles, but the exact limits upwards and downwards to which the fibres pass are not known, nor is it clear how many of the fibres are ascending and how many descending. Again, the sources and terminations of these ascending and descending fibres are but little known. The bundle certainly receives fibres from the Nuclei of many Sensory Cranial Nerves, especially from the Vestibular Nuclei. If it is a Sensory tract it does not run uninterruptedly to the Cerebral Cortex as was once held, but is certainly broken at the Optic Thalamus. To sum up Barker says that the truth with regard to this tract may very probably be found in the mean between such opposed views as those of Bechterew, Kölliker, Held and Gehuchten so that it may be looked on as built up of

two sorts of fibres, (1) ascending or centripetal both long and short by means of which Motor Nuclei may be affected by incoming impulses from various Sensory Nerves, and possibly also sensation conveyed towards the Cerebral Cortex. (2) descending or centrifugal by means of which Motor Nuclei in the Rhinencephalon and Cord are brought under the influence of centres in the Mid Brain or perhaps in still higher levels.

Sherrington⁶⁰ (1900) refers to the Posterior Longitudinal Bundle as a very complex strand formed in part of descending fibres, constituting a reflex path from visual and auditory centres to Spinal Cord Motor mechanisms, especially as regards the Cervical part; also it contains ascending fibres derived from those cells in the Anterior Horn of Grey Matter of the Cord which form Lenhossecks Commissural group. These fibres pass up to end in relation to various Cranial Motor Nuclei, particularly to those of the Eye Muscle Nerves. Yet further, there are to be found in this bundle Commissural or Association fibres connecting the Nuclei of the various Eye Muscle Nerves.

On comparing the views of the investigators quoted above, it becomes obvious that we are dealing with a most complex system of fibres, about the origin, course and distribution of which very different opinions may be held. On one point at least there is practically unanimity; almost all are agreed that the Posterior Longitudinal Bundle is closely associated with the Nuclei of origin of the nerves destined for the Eye Muscles. From Duval and Laborde onwards this relationship is noted, the only exception being in the case of Von Gudden who, from his observations in the Mole, denies any connection between this bundle and the Third Nucleus. Even when the fact of this connection is granted there is still difference of opinion as to its nature; for, while some describe the bundle as transmitting fibres from the Nucleus of one nerve into the actual trunk of another (Duval and Laborde, Gee and Tooth, Tooth and Turner), others regard the connection as one established between the different Nuclei only (Bechterew and Sherrington). Then with regard to the long fibre systems contained in this tract, two groups are described by different observers, (1) an ascending set derived from cells in the Spinal Cord whose destination appears to be either the Third Nucleus or some neighbouring

collection of Grey Matter (Tschermak and Held), and (2) a descending set arising either from a special Nucleus (Nucleus of Posterior Longitudinal Bundle of Van Gehuchten) or from the Grey Matter of the Corpora Quadrigemina (Held) or from some region anterior even to this (Boyce), and passing down to end in relation to cells in the Anterior Horn of the Spinal Cord. These two groups being regarded the former as an afferent (Sensory) tract conveying impulses upwards from lower to higher levels, the latter as efferent (Motor) carrying impulses in the reverse direction. These then are the generally advanced statements with regard to the structure and functions of the Posterior Longitudinal Bundle at the present time.

Turning now to the work done personally in regard to the relations and functions of this strand a few words are necessary as to the operative procedure adopted. This was practically the same for the whole series of animals experimented on, so that a single general description may serve for all. In every case the animal was fully under the influence of an Anaesthetic during the whole of the operation, Ether being used with, in some cases, the addition of a hypodermic injection of Morphia. The skin in the area around the region to be

operated on was shaved and carefully cleansed by repeated applications of Carbolic Lotions (1-20), while all instruments, as well as the wool used for swabs, were sterilised by boiling. All being thus prepared an incision was made in the middle line of the back of the neck extending from about the middle of the Occipital Bone down to about the level of the 3rd Cervical Spinous Process; the deep Nuchal Muscles were displaced laterally (if necessary their Occipital detachments being divided) and a complete view was thus obtained of the surface of the Posterior Occipito-Atlantal Ligament. All bleeding having been stopped and all antiseptic lotions abandoned for the use of sterilised (boiled) water, the Ligament was divided and cut away from its Occipital attachments. Then by putting slight traction on the head and flexing it fully, a very complete view could be obtained of the floor of the Fourth Ventricle and of the Inferior Vermis of the Cerebellum above. In some cases a small amount of the Occipital Bone was removed to give more room, but this was not found generally necessary, as the exposure given by the division of the Ligament was ample and avoided the risks of severe haemorrhage from the diploe, such as is often fatal, especially in cats. The lesion was next produced by the use


of a fine pointed Galvano-Cautery, applied either mesially (if the object was to divide the Posterior Longitudinal Bundle) or laterally (if ~~Dieters'~~ Nucleus was aimed at) to the floor of the Fourth Ventricle about the level of the Auditory Striae. The wound was then closed, a few deep horse-hair sutures holding together the muscular strata, a continuous suture of the same being used for the skin wound which was then covered with a wool and collodion dressing. In every case the wound healed by first intention; no septic trouble of any sort being met with. The animals all recovered quickly from the shock of the operation. A period varying from 14 to 32 days was allowed to elapse after the operation, and the animal was then killed by an overdose of chloroform; the Brain and Cord immediately removed and prepared for examination. The method adopted was that of Marchi, in which the material, after a preliminary hardening in Muller's Fluid for 10 days, is submitted to the action of a mixture of 1% Osmic Acid Solution and Muller's Fluid in the proportions of 1-2 for a further period of 10 days. Of the various suggested modifications of this method two were tried, those of Vassale^{40.} and Orr;^{52.} in the former Nitric Acid is added to the Osmic Acid Solution, and in the latter

Acetic Acid is used with the object of increasing the penetration of the Osmic Acid. Vassale's method was found to render the tissues very friable without appreciably increasing the reaction to the staining fluid; Orr's method was also found not to have any great advantage over the original method of Marchi, which provided that the slices of tissue were thin enough (not more than one-eighth of an inch thick), and that care was taken to prevent evaporating of the Osmic Acid from the solution, penetrated well. The only modification introduced was the substituting in some cases of 5% Formal for the Muller's Fluid used in the first stage of the process; after a nervous tissue has been for 5 days in this solution it is so far hardened that the very thin slices necessary to insure the penetration of Marchi's Fluid can easily be cut (a point of practical difficulty in tissues which are still quite soft after 10 days in Muller's Fluid). The reaction of the degenerated fibres is not in the least impaired; indeed they stand out all the more plainly as the rest of the tissue has not the deep yellow colour of Muller hardened material. *

The Formal Solution needs to be completely removed from the tissue by prolonged washing in running water before it is placed in Marchi's Solution; or

* The animals thus treated were Monkeys VIII and VII and Cat X.

reduction of the Osmic Acid may occur. On the completion of the staining and hardening process the material was passed through an ascending series of Alcohols into Xylol and from this into Paraffin in which it was embedded for cutting. In reference to the Marchi method Halliburton and Matt²⁹ have recently thrown fresh light on the chemistry of the process by showing that degeneration of medullated nerves is associated with a progressive diminution of Phosphorus in their composition; in other words, the normal Lecithin is replaced by a non-phosphorised fat, and it is this which is stained black by the Osmic Acid Solution, while the normal (Phosphorus containing) fibres remain unaffected; in old-standing degenerations this fat is absorbed, and the tissue no longer responds to Marchi's solution.



After embedding, the different segments into which the Brain and Cord had been divided were cut in serial sections by the Cambridge Microtome. The sections were made fairly thick (from 8-15 micros) in order that any Collaterals arising from the fibres might be more easily traced. The sections were mounted in Canada Balsam in the usual way. In those cases in which the region of the lesion had been embedded unstained after Formal hardening the serial sections were stained with Toluidin

blue after the method recommended by Professor Schäfer.⁵⁵

Passing now to the examination of the material thus prepared, it was found that three main groups of results were met with, these depending on the position of the area of destruction caused by the Cautery. These groups may be classified as follows :-

(1) Those in which the Posterior Longitudinal Bundle alone was injured; the results here varying in an interesting manner according to the level at which the bundle was cut, so that at least two sub-groups may be recognised (a) where the Posterior Longitudinal Bundle was divided below the level of the entrance of fibres derived from Deiters' Nucleus and (b) where the bundle was cut above the level of such entering fibres.

(2) Those cases in which the lesion had destroyed Deiters' Nucleus either alone or together with other structures.

(3) Not the least important group is formed of those cases in which the lesion has fallen in the lateral part of the floor of the Fourth Ventricle on the inner (mesial) side of Deiters' Nucleus and has divided certain of the strands emerging from this.

Turning next to the detailed examination of

the different members of the above groups, the first is found to contain five animals, 2 monkeys and 3 cats. Taking the monkeys first, the animal from which the preparations labelled M.VIII were made was operated on in the usual manner, the Cautery being applied to the middle line of the floor of the Fourth Ventricle. The animal recovered very rapidly and completely from the operation, so that even on the second day little abnormal could be seen. On examination it presented none of the eye changes which were met with in many of the other cases; there was no Nystagmus nor squint and the pupils were equal and reacted normally. There was no Motor Paralysis nor any tendency to assume a special attitude. Sensation appeared quite unimpaired, the animal responding at once to a touch or prick. On repeated examinations at later dates no further details could be made out. The animal was killed 28 days after the operation. The region of the lesion was stained with Toluidin blue, the rest of the Brain and Cord being treated by Marchi's method.

Before passing to the actual description of the appearances met with, a few words of explanation as to the method adopted to illustrate the text are

necessary. Drawings, photographs and the actual specimens are submitted. The drawings were prepared in the following manner; the outline and the more obvious features of the section were traced under the Camera Lucida at a magnification of about 5 diameters, and then the more detailed structure and the degenerations were put in under a considerably higher power. These drawings were made in the cases of the six most typical animals, and are included in the text.

The photographs are submitted in a separate album and are fully described there. It will, however, be found that the actual specimen as viewed under a fairly low power of the microscope (40 - 50 diameters) gives generally a more convincing picture than the photograph, as there are many difficulties in the way of getting a satisfactory negative from a somewhat thick specimen prepared by Marchi's method.

To prevent constant repetition and cross references in the text, the indicating number of the slide from which the drawing or photograph was taken is given along with the figure or print; although with regard to the drawings it will be found that in some cases the appearances of a series of sections are combined into one picture.




Fig. 1. (M^{VIII} Lesion 6.).

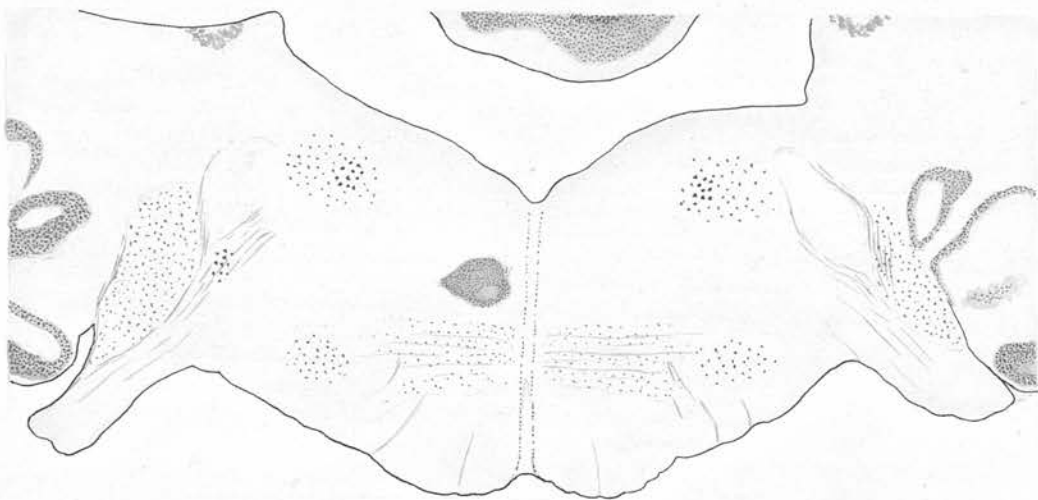
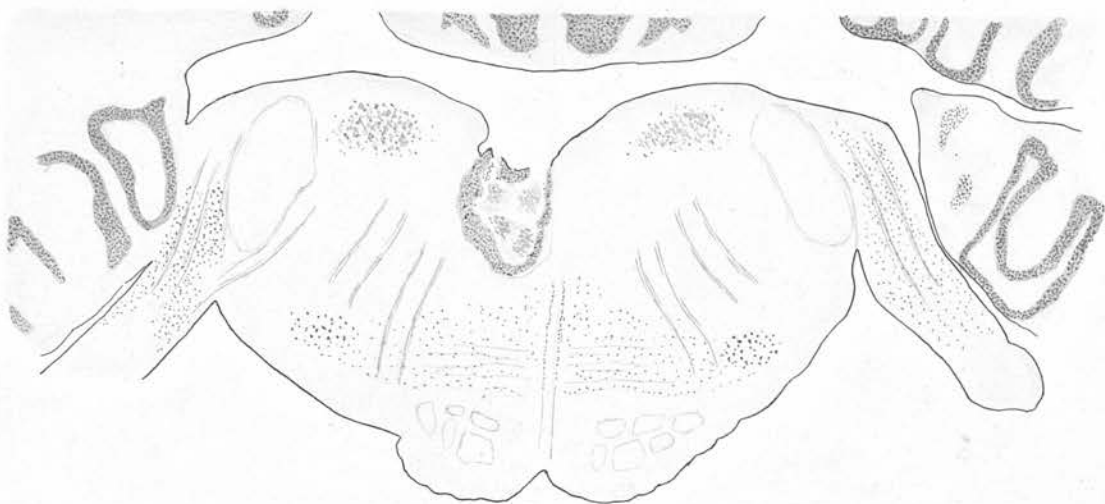


Fig 2 (M^{VIII}. Lesion 2.).

Coming then to the material furnished by Monkey VIII:- the lesion appears in the upper Medulla as a sharply defined area of granular debris lying to the right of the middle line but dipping below the surface of the floor of the Ventricle as it is traced forwards, so that in its anterior part it comes to lie in the lower Pons where it appears as a rounded area about 2 m.m. below the level of the floor. This position of the lesion is noteworthy for it shows that it does more than divide the Posterior Longitudinal Bundle of the right side in the Medulla, it has injured any deep fibres entering the bundle of the left side from Deiters' Nucleus of the right, such as are described by Cajal sweeping below the Sixth Nucleus to reach the bundle. (Plate I, Figs 1 and 2.)

Taking next the parts below the lesion, we come first to the lower Medulla. Here there is a faint trace of the lesion still showing affecting to a small extent the left side; both Posterior Longitudinal Bundles show degeneration. The right one is the more markedly affected, and lateral to it there is some degeneration in the Formatio Reticularis. Further, the right Fillet contains some blackened fibres at this level suggesting injury to the Posterior Column Nuclei. (Plate II, Fig.1.)



Fig. 1. (M.VIII γ(2)).

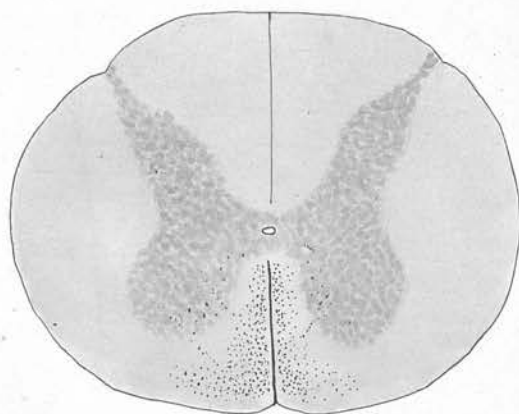


Fig. 4. (M.VIII 10(2)).

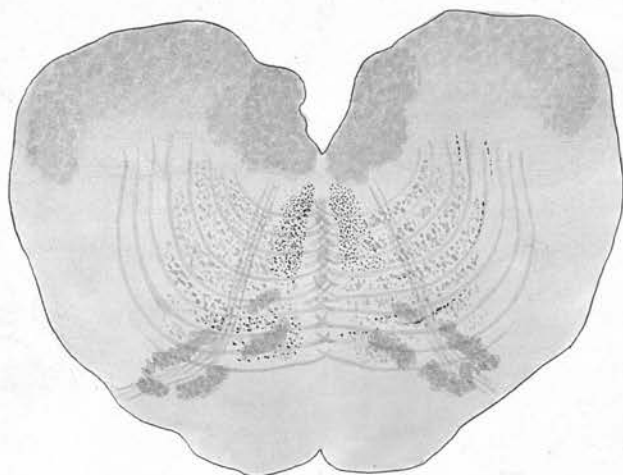


Fig. 2. (M.VIII γ(9)).

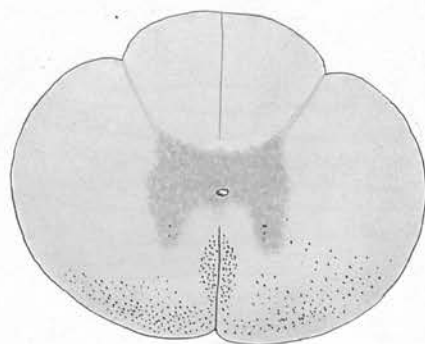


Fig. 5. (M.VIII 11(0)).

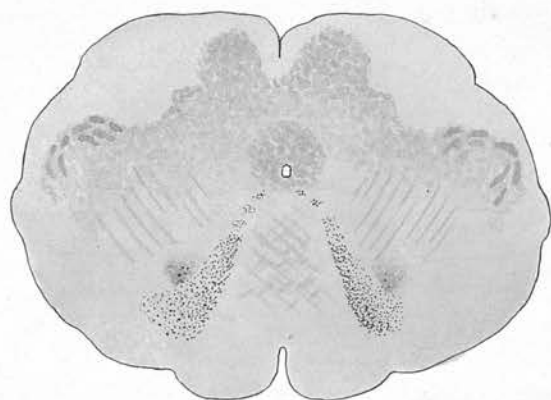


Fig. 3. (M.VIII 8(5)).

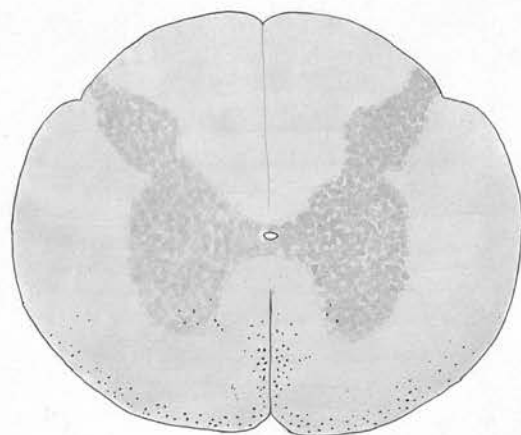


Fig. 6. (M.VIII 12(4)).

On examining the series of the lowest Medulla a few Arcuate fibres are seen sweeping from the left side and crossing in the Sensory Decussation to reach the right Fillet. The Posterior Longitudinal Bundle degeneration remains the same. (Plate II, Fig. 2.)

Coming next to the level of the decussation of the Pyramids the Posterior Longitudinal Bundles have spread ventrally and appear as two black strands bordering the Pyramidal fibres and intervening between these and the Grey Matter which is beginning to form the Anterior Horns. The degeneration still predominates on the right side. Fine degeneration begins to show in the Anterior Horns at this level. (Plate II, Fig. 3.)

In the first Cervical Segment the difference between the two areas of degeneration is more marked, that on the left side being almost confined to the side of the Anterior Median Fissure, while on the right it has spread somewhat ventrally round the Anterior Horn; much fine degeneration shows in the Grey Matter here. This description also applies to the appearances in the Mid Cervical Cord where also there is somewhat more lateral spread of the degeneration. (Plate II, Fig. 4.)

Passing to the Mid Dorsal Cord a curious

change in the appearance of the degeneration is seen. It is much wider spread and shows as nearly equal on the two sides, this equality being apparently due to the ending of some of the degenerated fibres of the right side; there is comparatively little degeneration in the Anterior Horns here.

(Plate II, Fig. 5.)

Coming next to the Mid Lumbar Cord the degenerated strands now form two nearly equal narrow marginal areas extending along the Anterior Median Fissure and the periphery of the Cord, not reaching the bottom of the Fissure nor extending as far back as the Crossed Pyramidal Tract. (Plate II, Fig.6.)

Passing now to the parts above the lesion we find much less sign of degeneration. In the Pons there is a small amount of change in the left Posterior Longitudinal Bundle, none at all in the right; but a few degenerated fibres show in the Formatio Reticularis external to this; the right Fillet degeneration shows well here. (Plate III, Fig.3).

Ascending to the Posterior Corpora Quadrigemina the same appearances hold, slight degeneration in the left Posterior Longitudinal Bundle, none in the right. The Fillet is seen leading away laterally. In the Anterior part of this region the Third Nucleus begins to appear and on the left side there is fine

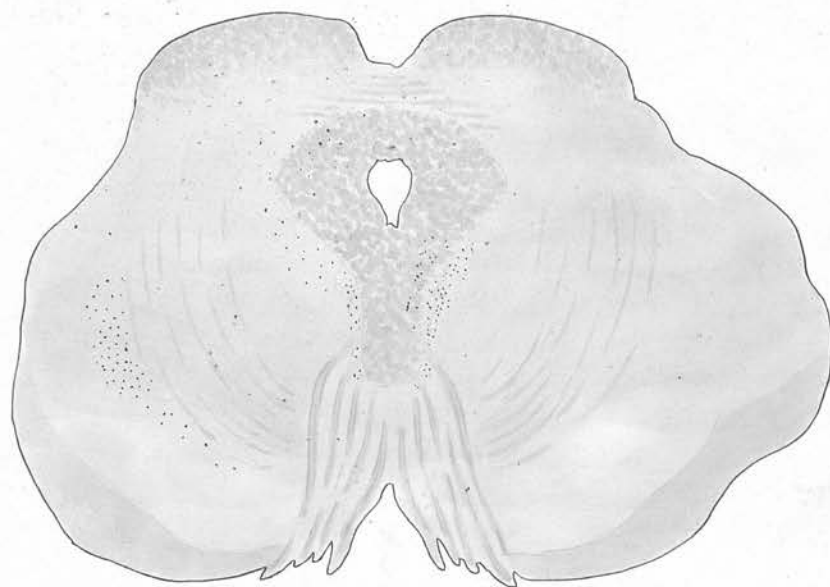


Fig. 1.
(M VIII. 4 (3))

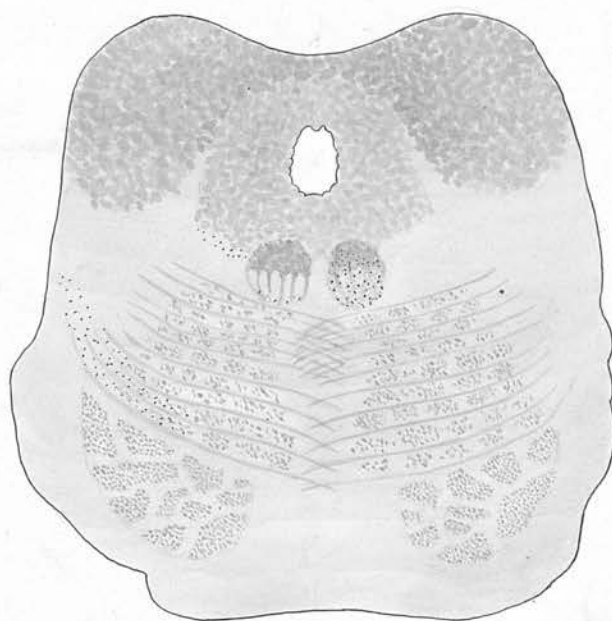


Fig 2.
(M VIII 5. (1))



Fig. 3.
(M VIII. 6 (7))

degeneration in this entering from the Posterior Longitudinal Bundle. (Plate III, Fig.2.)

Turning next to the region of the Anterior Corpora Quadrigemina we find the two bundles approximating at their inner (lower) ends enclosing the Grey Matter of the Third Nucleus. There is now less degeneration in the left bundle, but it continues to give off numerous fine branches which ramify in all directions amongst the Ganglionic Cells of the Motor Oculi Nucleus. The Fillet on the right side is seen leading up towards the Anterior Corpus Quadrigeminum, many of its fibres being cut almost longitudinally. The scattered degeneration which is before noted external to the right Posterior Longitudinal Bundle is now seen more Dorsal in position lying lateral to the central Grey Matter. In the anterior sections of this series the emerging roots of the Third Nerve are seen, and rapid diminution of the degeneration in the left Posterior Longitudinal Bundle is to be noted. (Plate III, Fig.1.)

On examining the sections of the brain through the Posterior part of the Optic Thalamus very slight signs of degeneration are to be seen except in the Fillet whose fibres can easily be traced sweeping outwards laterally to reach and ramify amongst the

Fig 1. (M^{VIII} 2(1)).

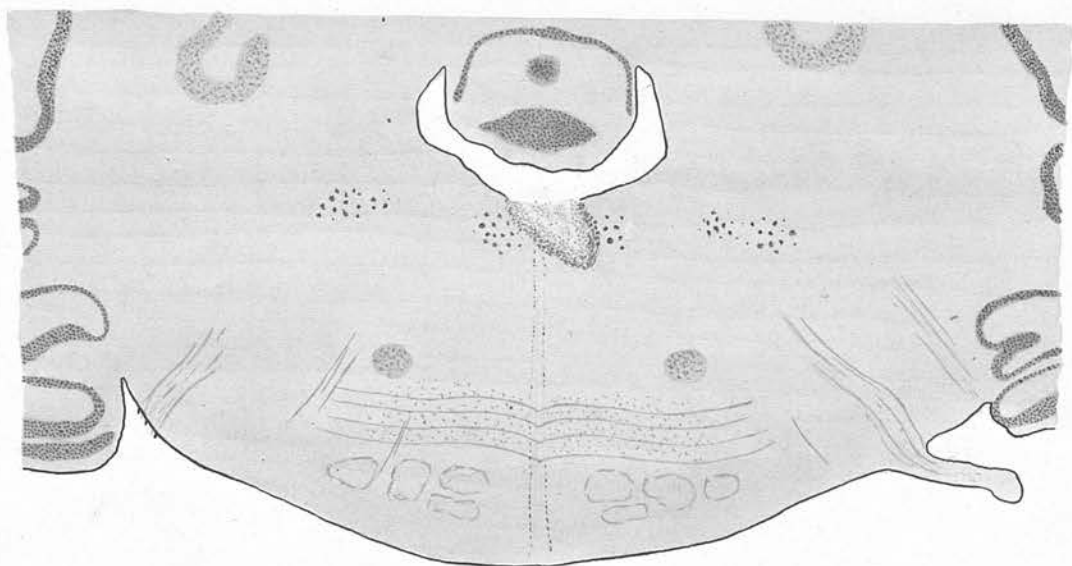
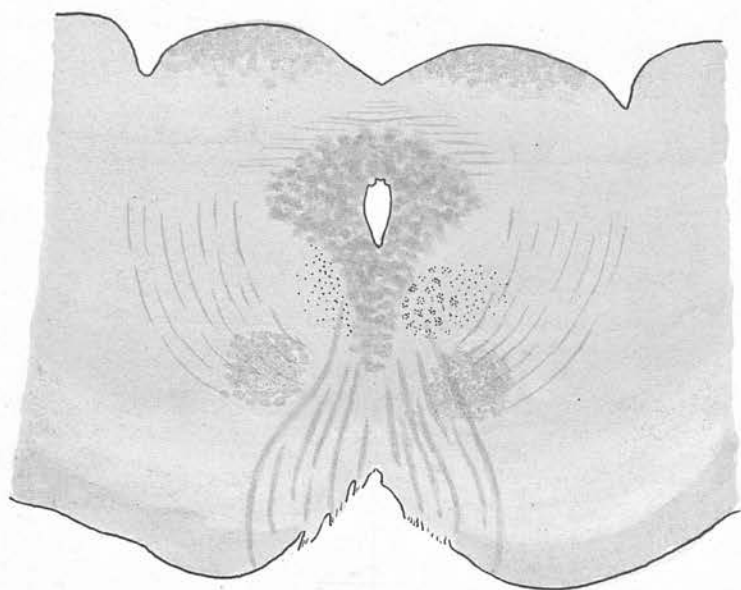


Fig 2. (M^{VIII} Lesion 7.).

the Brain and Cord were treated by Marchi's method. Turning first to the lesion, it is found in this case to occupy a position in the lower Pons; that is to say at a higher level than in the case just described. It is a mesially situated, sharply defined area somewhat wedge-shaped on transverse section passing rather deeper on the left than on the right side. The injury done here is interesting, the Sixth Nucleus of the left side is destroyed, the left Posterior Longitudinal Bundle is completely cut, while the right is somewhat less injured. The lesion here lies at the level of the position of Deiters' Nucleus, the characteristic large cells of which show clearly in the lateral part of many of the sections. (Plate IV, Fig.2.)

Passing to the parts below the lesion first, there is in the lower Medulla an almost symmetrical degeneration of both Posterior Longitudinal Bundles, the left one being perhaps the more marked. In sections through the level of the emerging Hypoglossal Nerves these are seen to limit the lateral spread of the degeneration; there is some fine degeneration in the Nucleus of the left nerve.

On reaching the lowest Medulla the ventral spread of the Posterior Longitudinal Bundles is well seen. They now form continuous strands of degeneration from just below the central canal to the level

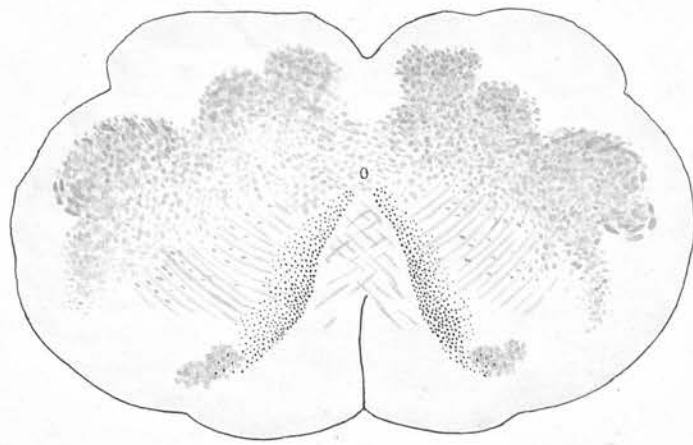


Fig. 1 (M VII. $\gamma(2)$).

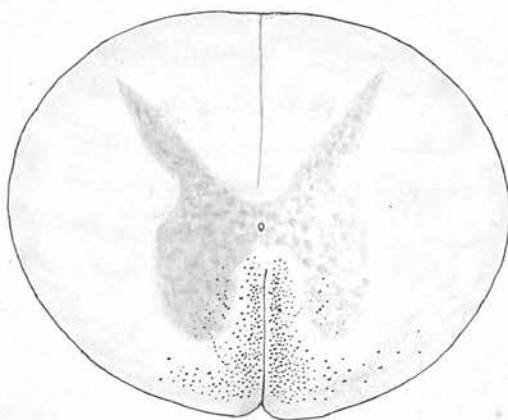


Fig. 2 (M VII 8.(3)).

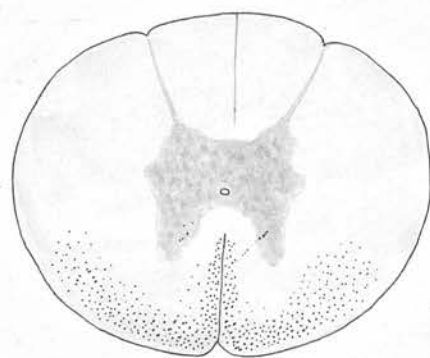


Fig. 3. (M VII q.(2)).

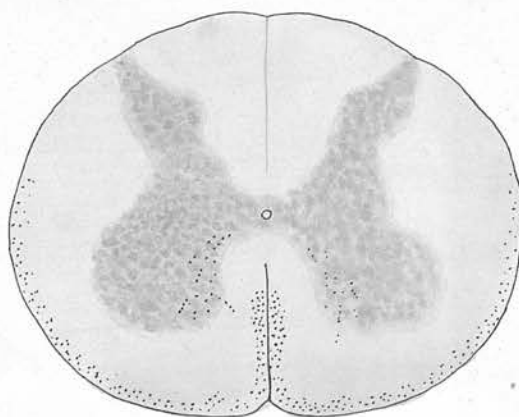


Fig. 4. (M VII. 10(4)).

of the inferior Olive. (Plate VI. Fig. 3.)

Coming next to the level of the Pyramidal Decussation the appearances are very similar to those in Monkey VIII. Two curved strands of blackened fibres framing in the crossing Pyramids and separating them from the still isolated Grey Matter of the Anterior Horns, to which many fine fibres pass. (Plate V, Fig.1).

On reaching the Cervical Cord the similarity to the former specimens is again marked. There are again two somewhat L shaped areas of degeneration, one limb of this is very strongly marked, lateral to the Anterior Median Fissure; the other extends outwards parallel to the margin of the cord but not reaching the margin being separated from this by a thin strand of normal fibres. (Plate V, Fig.2.)

In the Mid Dorsal Cord the lateral portion of this L shaped area is much scattered and occupies a large part of the Antero-Lateral Columns on each side. The more mesial part still extends along the Anterior Fissure for its whole length. Very few fibres can be traced to the Anterior Horns here. (Plate V, Fig.3.)

In the Mid Lumbar Cord the position of the degeneration has again changed, and two long thin tracts are seen lying quite marginal and extending

Fig 1. (M.VIII. 4(6)).

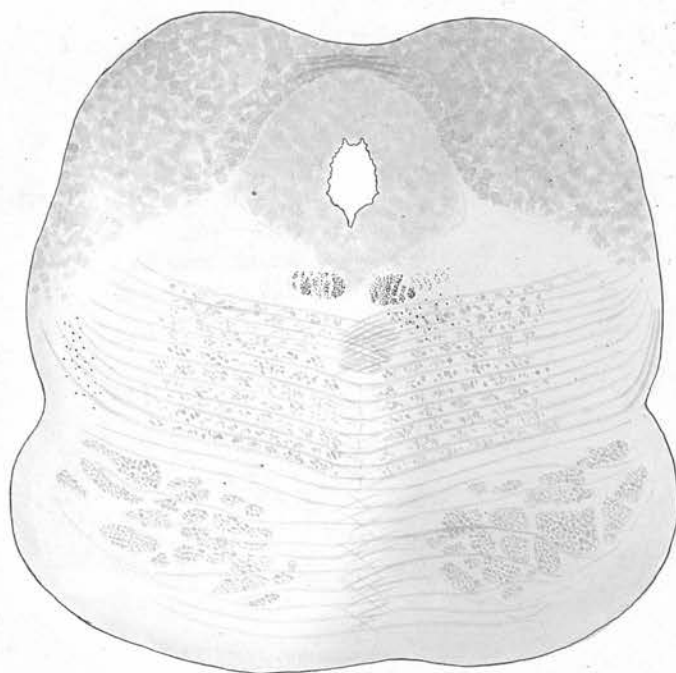


Fig 2 (M.VIII. 5(4))

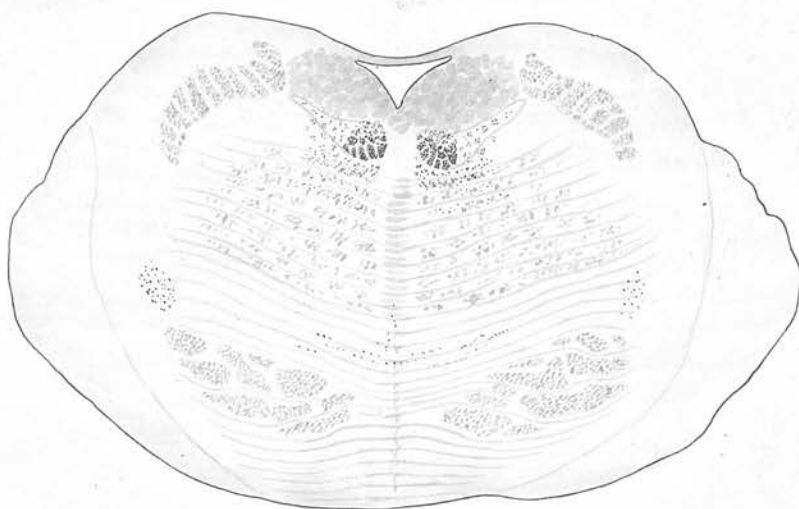
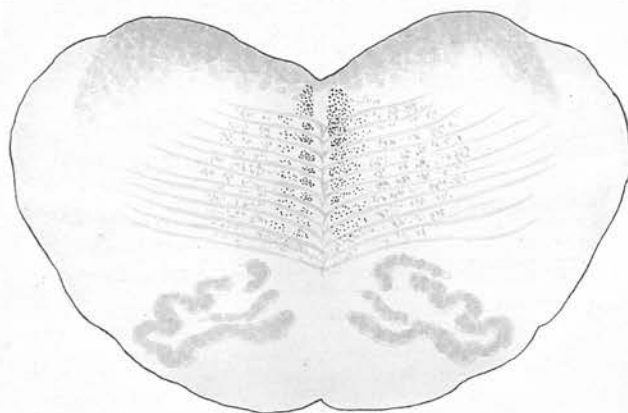


Fig 3. (M.VIII. 6(4)).



round the Cord for nearly half its circumference. Here again there is much fine degeneration scattered in the Grey Matter of the Anterior Horn. (Plate V, Fig.4).

So far, then, the appearances in these two animals have been very similar; but on turning to the parts above the lesion we find very striking and suggestive differences. Taking first the Mid Pons, here the most outstanding feature is the profound and symmetrical degeneration of both Posterior Longitudinal Bundles. These appear as two deeply blackened irregularly circular strands lying close to the mid line just ventral to the floor of the Fourth Ventricle. The lower and inner portion of each bundle shows the most marked change. It is also noticeable that a small area of lateral degeneration occupies the position of the lateral Fillet. This occurs on both sides, but is very faint on the left. (Plate VI, Fig.2.)

Passing next to the region of the Posterior Corpora Quadrigemina, both Posterior Longitudinal Bundles again show great degeneration. In the Formatio Reticularis also a few degenerated fibres are seen, especially on the left side lying ventral to the Posterior Longitudinal Bundle. The degeneration in the lateral Fillet is seen passing up

towards the Grey Matter of the Corpora Quadrigemina on the right side. It is very slightly marked on the left. In the anterior part of this segment the Third Nucleus begins to appear and is thickly dotted with fine degeneration on both sides. (Plate VI, Fig.1).

Coming to the Anterior Corpora Quadrigemina, the lower portion of this was treated by Nissl's method with the view of bringing out any Chromatolysis which might have occurred in the cells of the Third Nucleus as the result of the damage to the Posterior Longitudinal Bundle, there is strikingly little change, perhaps a few cells show abnormally faint staining but no marked Chromatolysis has occurred, a point of some interest. The extreme anterior part of the Anterior Corpora Quadrigemina was again stained by Marchi's method, and the greatly reduced amount of degeneration in the Posterior Longitudinal Bundles is very noticeable; but still fine entering fibres can be traced to the Third Nucleus. (Plate IV, Fig.1.)

On reaching the level where the Aqueduct opens out into the Third Ventricle, the two bundles are still indicated, although the amount of degeneration is greatly reduced. They still occupy the same relative position as they did to the Aqueduct.

Coming next to sections taken through the brain in the posterior parts of the Third Ventricle the degeneration can still be followed with difficulty on either side of this, as two small strands passing apparently upwards and outwards. More anteriorly these fibres are traceable towards the Optic Thalamus in which they appear to end. Beyond this level no degeneration could be traced.

This case makes an excellent one for comparison with Monkey VIII. The Cord degeneration is practically the same in both, but in the present case there is very marked degeneration anterior to the lesion, contrasting with the few fibres traceable in the former case. The reason for this difference is to be looked for in the different levels at which the lesions lie, so that fibres entering the Posterior Longitudinal Bundle which have escaped damage in Monkey VIII have been cut across and are degenerated in Monkey VII.

Turning next to the Cats which fall to be included in this group owing to the lesion having divided the Posterior Longitudinal Bundle, we will examine first the series labelled Cat X. The operation in this case was performed as before, the Cautery being applied to the floor of the Fourth Ventricle in the middle line. There was very

severe bleeding in this case as a portion of the Occipital Bone was removed. This was ultimately stopped by rubbing in sterilised wax into the Diploe. When examined the day after the operation the animal appeared quite unable to stand, rolling over helplessly on to its right side. There was very marked lateral Nystagmus and a curious constant twitching of the eyelids and facial muscles generally. Later when examined out of its cage the animal showed incoordination of movement, not being able to advance directly to the object aimed at. There seemed to be no sensory change, response to touch or prick being quite sharp on either side. On the 5th day the Nystagmus had almost disappeared and, except for a slightly stiff gait and an occasional slip to the right side, movement was little impaired. The animal was killed sixteen days after the operation. On examining the lesion it is found to be situated in the anterior part of the floor of the Fourth Ventricle at the level of the Genu Facialis. It is superficial in character but is wide-spread laterally, having injured both facial nerves where the Genu reaches the surface. The Posterior Longitudinal Bundles are both damaged in their more superficial parts, and the Sixth Nucleus is also slightly injured. The Inferior



Vermis appears to have been cut by the Cautery and its involvement probably accounts for some of the symptoms in this case. (Slide - C.X. 7. 4.)

Turning to the parts below the level of the lesion degeneration is found well marked in both Posterior Longitudinal Bundles in the Medulla, and at the level of the decussation of the Pyramids these sweep round to join with the Antero-Lateral Columns as noted in the previous cases. At this level also the entrance of fine fibres into the Anterior Horn is well seen. (Photo -C.X. 2.)

Coming to the Cervical Cord the amount of degeneration is considerably less than in the previous cases, and is almost limited to the sides of the Anterior Median Fissure, only a slight lateral spread occurring. The degeneration is especially thick towards the bottom of the Fissure.(C.X. 11.1).

In the Dorsal Cord the L shaped appearance of the degenerated area is again to be seen, and it is of interest to note that here again the degeneration is separated from the surface by an area of normal fibres. (Slide - C.X. 12.3).

Finally, coming to the Lumbar Cord the degeneration is greatly reduced in amount being composed now of scattered fibres which occupy a similar area to that just noted. There are again a few entering

fibres to the Anterior Horns.

On passing to the parts anterior to the lesion we find similar appearances to those noted in Monkey VII. In the upper Pons both Posterior Longitudinal Bundles stand out as almost equally degenerated. There is also some fine scattered degeneration in the *Formatio Reticularis*, particularly of the right side; this is less marked on the left. There is also degeneration of the right Fillet probably due to the slight involvement of the Posterior Column Nuclei in the Medulla. (Photo - C.X. 1.)

On reaching the hindmost part of the Posterior Corpora Quadrigemina, the two Posterior Longitudinal Bundles still stand out clearly, and have taken on their characteristic pyriform shape, the degenerated fibres being now gathered more in the mesial portions of the bundle. A small amount of degeneration is to be noted in the decussating fibres of the Superior Cerebellar Peduncle. These appear to end in the lateral Grey Matter.

In the more anterior parts of the Posterior Corpora Quadrigemina the close relationship of the Posterior Longitudinal Bundles to the Fourth and Third Nuclei is well brought out, - the cells of the Fourth Nucleus first appearing with numerous black dots of degeneration amongst them, and at a

little higher level those of the Third Nucleus showing even more marked degenerated fibres around them. (The curiously pigmented nature of many of the cells in these Nuclei is not to be ascribed to any degeneration as it is frequently met with in the Motor Cells in the Cat). More anteriorly still the Third Nerves are seen emerging from their Nuclei and it is to be noted that there is no degeneration in these nerve trunks. (Slides -C.X. 4. 8 & 3.)

Reaching now the Anterior Corpora Quadrigemina the amount of degeneration in the Posterior Longitudinal Bundle is getting greatly reduced; but there is still a scattered strand of blackened fibres ventro-lateral to the central Grey Matter from which many fine fibres pass to end around the cells. in this, some of them apparently decussating. In the higher members of this series the degeneration becomes difficult to follow as it is dying away rapidly. Some fibres, however, are traceable to the region of Darkschewitsch's Nucleus, while others appear to run further into the Subthalamie region passing outwards in the direction of the Optic Thalamus. The degenerated right Fillet can be traced in all this series. (Slide C.X. 3. 9.)

To sum up the results obtained:- A superficial lesion situated on the course of the Posterior Longitudinal Bundle at the level of Genu Facialis has

again caused both ascending and descending degeneration. The former can be traced to the Eye Muscle Nuclei, and even beyond these into the Sub-thalamic region; the latter is found in the Antero-Lateral region of the Cord extending right down into the Lumbar part furnishing branches to the Grey Matter as it passes.

In contrast with the results obtained in Cat X are those found in Cats VIII and VII. Taking first Cat VIII; the operation was performed in the way already described, but the Cautey was applied to the lower part of the Fourth Ventricle. After recovery from the immediate effects of the operation there was little abnormal to note; the animal seemed somewhat disinclined to move and presented slight Ataxic symptoms, showing a broadened base of support, the hind legs especially being widely separated, and the gait on movement somewhat stiff. There were no eye changes of any sort in this case. Sensation was also unimpaired. The animal was killed fourteen days after the operation, and the Brain and Cord treated by Marchi's method.

On examination the lesion was found to be restricted to the Medulla, not reaching as far forwards as the Pons. In the upper Medulla it appears as an oval area chiefly affecting the right side

and extending for about 2 m.m. into the Grey Matter below the floor. In its lower part the lesion is seen to have spread to the left side so that both Posterior Longitudinal Bundles are cut across in this part of their course. A slight involvement of the Twelfth Nucleus has caused a few fibres in this nerve to degenerate. There is also some damage to the Posterior Column Nuclei with resulting change in the Arcuate fibres which are seen sweeping across in the lower Medulla. (Slide - C.VIII. 5A3.)
and 6.2.

At the level of the Pyramidal Decussation two densely black degenerated areas are seen lying in each case internal to the commencement of the Anterior Horn; the one on the right side being prolonged to encircle the Horn. Fine degeneration is traceable to the Grey Matter on both sides, but specially to that of the right. (Photo - C.VIII. 1.)

In the Mid Cervical Cord, very definite areas are affected; on the right side a dense strand of degeneration shows beside the Anterior Median Fissure, and extends laterally along the margin of the Cord almost reaching the surface. (Photo C.VIII 2.) On the left side the degeneration is limited to the region of the fissure, and is not quite so marked. In both cases many fibres pass to the Anterior Horn, the resulting fine degeneration being

particularly marked around the more mesial group of ganglion cells.

The degeneration gradually spreads laterally as it passes downwards until in the Mid Dorsal Cord a much more scattered region is affected as regards the right side; the amount of degeneration on the left is now much less, the entering fibres to the Grey Matter are also fewer. (Photo - C.VIII. 3.)

This progressive diminution continues so that in the Mid Lumbar region the blackened fibres are only seen clearly to the right of the Anterior Fissure, some scattered degeneration being seen lateral to this. On the left side the degeneration is greatly reduced. Entering fibres, however, are again seen passing to the Grey Matter, quite a recognisable amount of fine degeneration being visible around the mesial group of cells. (Photo - C.VIII. 4.)

Passing now to the parts anterior to the lesion, we find a somewhat similar condition to that noted in Monkey VIII; there is very slight ascending degeneration in the Posterior Longitudinal Bundle, less even than in M.VIII. In the Pons, not more than a dozen degenerated fibres can be seen in the bundle, contrasting with the large number in Cat X. There is, however, a little degeneration in the *Formatio Reticularis* lateral to the bundle. The main degeneration is that affecting the Fillet

which may be ascribed to the injury noted to the Posterior Columns in the Medulla. In sections through the higher part of the Pons, the amount of degeneration is so slight, except in the Fillet, that it was not traced further forwards. (CVIII. 5.4.).

In this case, then, a lesion deep enough to completely cut the right Posterior Longitudinal Bundle has caused a marked descending degeneration, but hardly any ascending change. The more widespread degeneration in the Cord here, as compared with Cat X, can fairly be associated with the greater damage to the bundles here, and also with the fact that the direct spinal tract appears to have been injured in the upper Medulla by the deeper part of the lesion to a small extent.

Cat VII may next be examined, as here again a slightly different lesion was produced. The usual operation was performed, care being taken to restrict the injury to one side of the mesial plane. After the shock of the operation had passed off, this animal also showed singularly little; no sensory changes could be made out; there was no Nystagmus nor other eye change - in fact, except for a slight stiffness in walking, the animal appeared perfectly normal, and so remained until it was killed 16 days after the operation. On localising the lesion, it was found as a small sharply

defined area of granular debris just external to the mid line in the lower part of the Medulla. It has destroyed in part the Nucleus of the right Hypoglossal Nerve, and has cut through the Posterior Longitudinal Bundle at this level. It is interesting to note the appearance of fine degenerated fibres leading across the middle line from the injured Twelfth Nucleus to that of the opposite side. There has again been injury to the Posterior Column Nuclei with resulting Fillet degeneration. (Slide - C.VII. 9. 2.)

Passing to the Medulla below the level of the lesion, a part of the right Hypoglossal Nucleus is seen uninjured and healthy fibres pass to this nerve here. Immediately ventral to this collection of nerve cells lies the definite rounded strand of the Posterior Longitudinal Bundle, the opposite bundle containing a few (about 30) blackened fibres as contrasting with some hundreds on the injured side. (Slide - C.VII. 10. 5.) In the lower Medulla the ventral spread of the Posterior Longitudinal Bundle fibres is well seen. Coming to the decussation of the Pyramids the area degenerated on the right side occupies the usual position between the crossing pyramidal strands and the Grey Matter of the Anterior Horn, not extending round the Horn in this case. (Slide - C.VII. 11. 3.) The

left side is practically clear of degeneration already. In Mid Cervical Cord, the degeneration takes up a position about midway between the Anterior Median Fissure and the inner aspect of Anterior Horn. It is seen to furnish fibres to the Anterior Horn of its own side and an occasional decussating fibre can be traced through the Anterior Commissure to the opposite Grey Matter. ^(C.VII. 12.3) In the [^]Dorsal Cord there is still the same area of altered fibres, but they are much reduced in number now. In the Lumbar Cord the degeneration is very slight being only indicated alongside of the Anterior Median Fissure, though a few black dots appear in the Anterior Horn. (C.VII. 14.3)

As in the previous case there is practically no degeneration to be traced upwards towards the Brain above the level of the region. The results, here then, are those of a sharply restricted lesion of one Posterior Longitudinal Bundle in its lower part, and they consist practically only of a descending degeneration.

If we now compare the general results obtained from these five animals, we find that in two (1 Monkey and 1 Cat) where the lesion occurred at the level of Genu Facialis, degeneration resulted in both Cranial and Caudal directions, spreading in

the brain at least to the region of the Third Nucleus and to a lesser extent beyond even this level, and traceable in the Cord as a distinct tract into the Lumbar region. On the other hand, in one Monkey and two Cats, the lesion was situated in the Medulla below the level above indicated, and it is of interest to note that practically there is no spread of degeneration brainwards, it was almost wholly restricted to the Cord, affecting the Antero-Lateral tracts in varying degrees according to the amount of Posterior Longitudinal Bundle involved in the lesion. It is obvious, then, that some fibres enter the Posterior Longitudinal Bundle at the level of the lower Pons which take a most important part in forming the ascending continuation of this strand; while one is driven to the conclusion that comparatively few of the fibres found in the lower part of the bundle can be regarded as ascending beyond the level of the Medulla. The further consideration of the source of this important ascending fibre system may, with advantage, be postponed until after the examination of the results following on lesions involving other structure in the vicinity of the Posterior Longitudinal Bundle.

Taking up now the second of the three groups into which the material falls for classification

we find that it includes those cases in which Deiters' Nucleus (Nucleus Nervi Vestibuli Lateralis) was injured either alone or along with other structures. This group includes two cases, both Monkeys, numbered in the series M.III and M.IV. In Monkey III the lesion is wide-spread; in Monkey IV it is practically restricted to Deiters' Nucleus. For this reason it may be better to consider this in the first place, and then compare the results with those obtained in the case of the larger lesion.

The operation in the case of Monkey IV was similar in all respects to those already described, except that when the floor of the Fourth Ventricle was exposed, the Cautery was applied to the lateral region about the level of the Auditory Striae (in both the cases to be considered, the right side was selected for the site of the lesion). There was very little to be noted abnormal as the result of the operation. A transient Nystagmus, which only lasted for 3 days, was practically the only sign of the injury. There was no impairment of voluntary motion, and sensation was apparently quite sharp. The animal was killed 30 days after the operation, and the Brain and Cord treated in the usual way.

On examining first the region injured by the Cautery, a superficial lesion was found in the upper

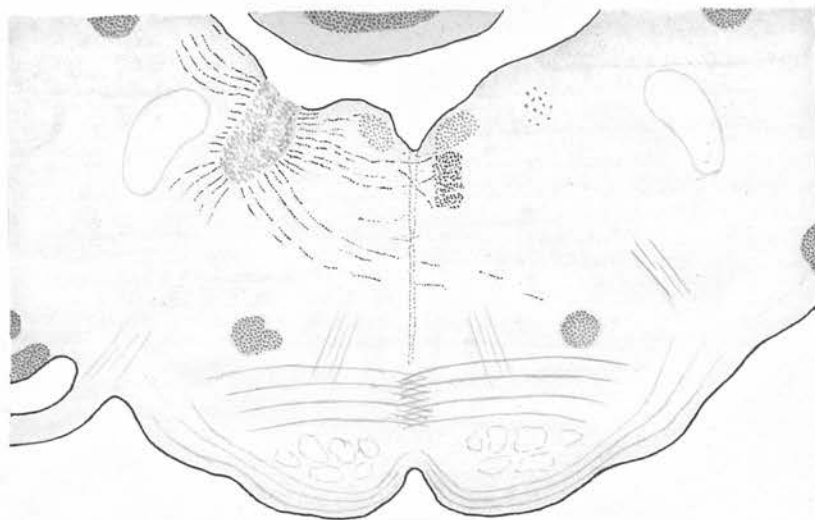


Fig 1. (MIV. 5(2)).

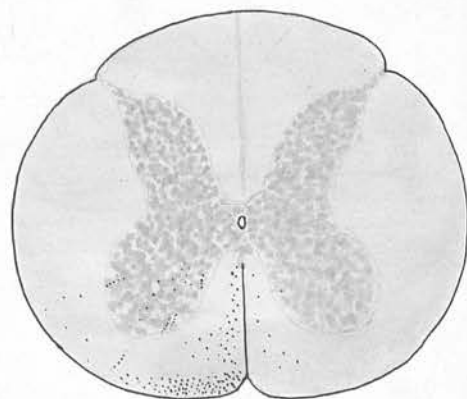


Fig 4. (MIV. 8(1)).

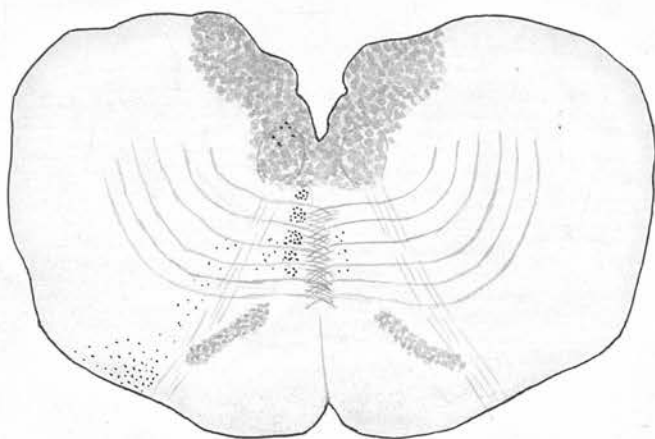


Fig 2. (MIV. 6(5)).

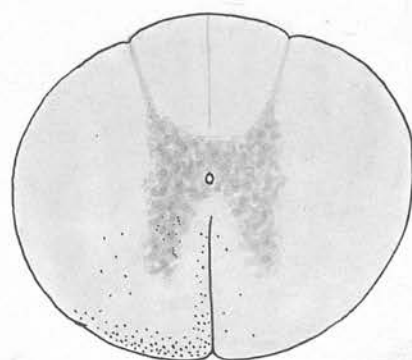


Fig 5. (MIV. 9(4)).

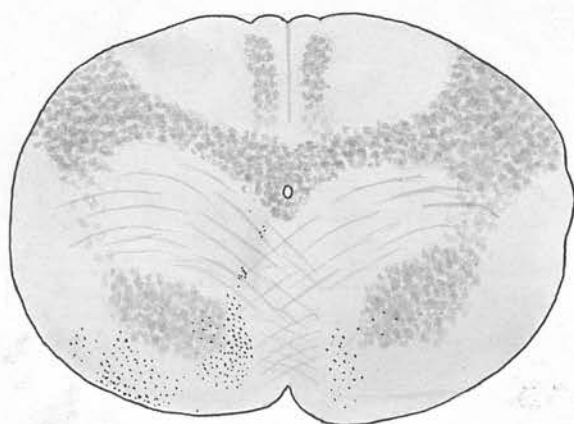


Fig 3. (MIV. 7(1)).

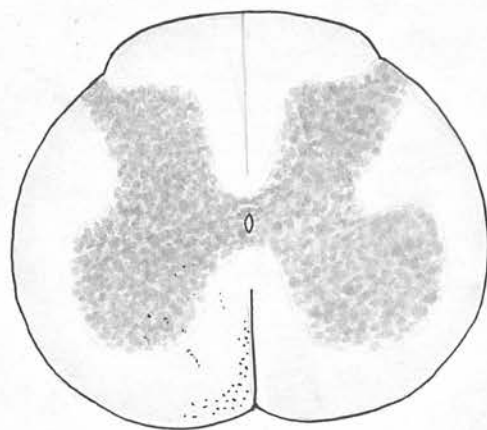


Fig 6. (MIV. 11(3)).

Medulla (which had been stained with Toluidin blue) extending much more deeply in the region of the lower Pons (which had been prepared by Marchi's method).

Here it lies well external to the Seventh Nerve which, together with the Sixth Nucleus, is quite uninjured. The position of this more anterior part of the lesion is such that Deiters' Nucleus must have been destroyed. Degenerating fibres can easily be traced radiating from the vicinity of the lesion. The most obvious pass inwards running in long sweeping curves towards the Raphe. There is a special collection of these fibres just below the floor of the Ventricle which cross the middle line and enter the opposite (left) Posterior Longitudinal Bundle. Of the more ventral fibres some pass to the Superior Olive of the left side, others apparently lose themselves in the *Formatio Reticularis*. The Sixth Nucleus shows some fine degeneration amongst its cells on both sides but especially on the right side. Many other fibres sweep outwards and upwards from the lesion to enter the Cerebellum (Plate VII, Fig. 1.)

In the Medulla just above the *Calamus Scriptorius* the Twelfth Nuclei and Nerves appear. Here the right Posterior Longitudinal Bundle shows as a

well marked strand of degeneration extending from just ventral to the Twelfth Nucleus (in which a few degenerated fibres are seen) nearly to the Inferior Olive. There is also some degeneration scattered lateral to this, and a small definite tract is seen lying Dorso-Lateral to the Olive in the position which we associate with the direct spinal tract from Deiters' Nucleus. On the left side there is a small amount of degeneration in the more ventral part of the Posterior Longitudinal Bundle.

Passing to the level of the decussation of the Pyramids two unequal areas of degeneration appear lateral to the space occupied by the crossing fibres. The area on the right side is well marked lying in contact with the collection of Grey Matter which marks the position of the commencing Anterior Horn. Many fine fibres can be traced to this from the degenerated tract. Also ventral to the Anterior Horn marked degeneration is seen. On the left side the much scantier degeneration lies also in relation to the Anterior Horn to which it furnishes fibres. (Plate VII, Fig.3.)

In the Cervical Cord the differences between the two sides as regards degeneration are well marked. On the right there is an extensive degeneration passing deeply along the side of the Anterior

Median Fissure and extending outwards along the periphery of the Cord for some distance; this degeneration is especially dense in the vicinity of the angle formed between the Anterior Fissure and the margin of the Cord in that region where, in many of the animals previously examined, a thin tract of normal fibres was noted. This is the site occupied by the fibres coming directly from Deiters' Nucleus in their spinal course. On examining the left side it is to be noted that the few blackened fibres seen here only occupy that part of the Anterior Column which lies close alongside the Anterior Fissure extending out no further than the region of the Anterior Nerve roots. From both of these degenerated strands fibres can be traced to the Anterior Horn. (Plate VII, Fig.4.)

In the Mid Dorsal region the same appearances hold for the right side. There has been a slight lateral spread of degeneration, but this is not marked. The left side is almost clear of degeneration now. Some fine degeneration still appears in the right Anterior Horn. Finally in the Mid Lumbar region the right sided degeneration is lessening in amount, and is found chiefly in relation to the Anterior Fissure; it still gives a few fibres to the Anterior Horn. The left side is quite clear of degeneration. (Plate VII, Fig.6.)

Fig 1. (MIV.2.(8).)

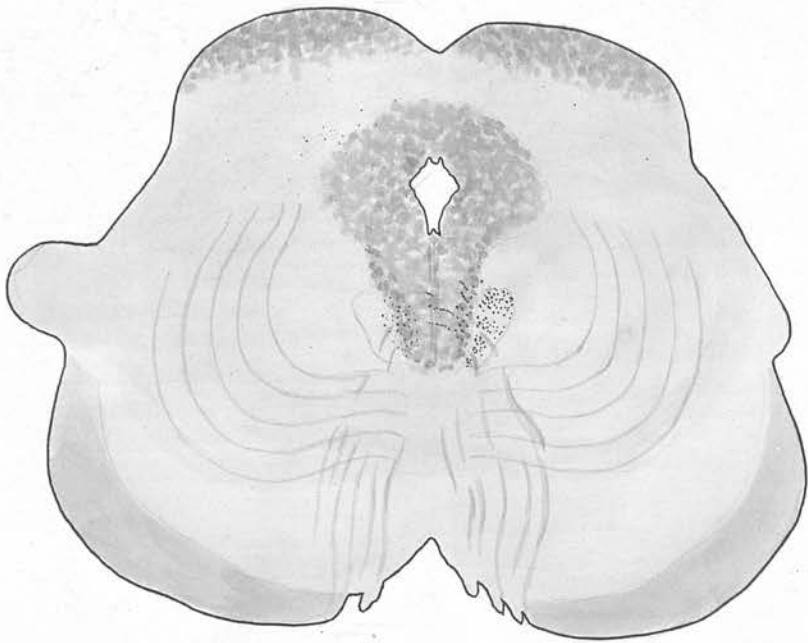


Fig 2 (MIV.3.(4).)

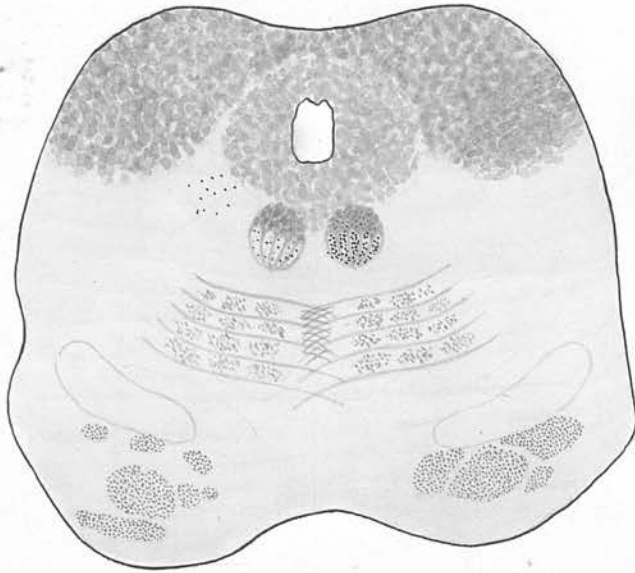
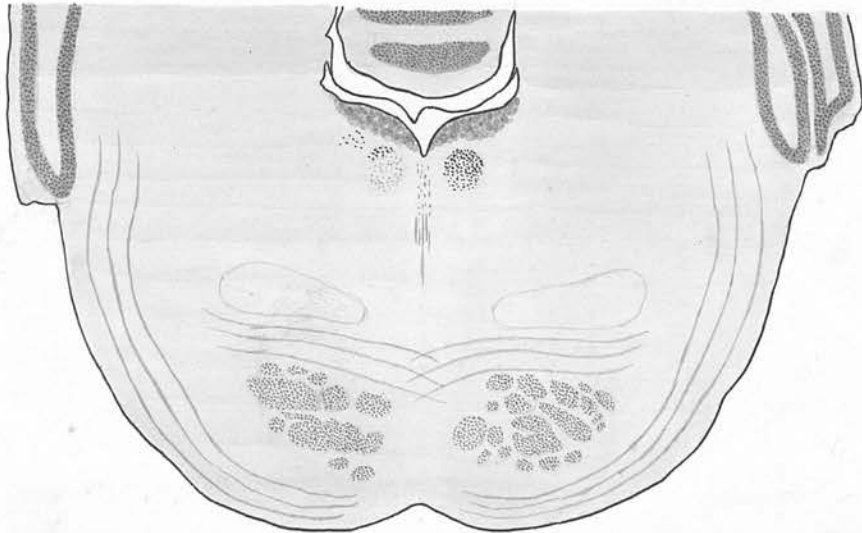


Fig 3. (MIV.4.(q)).



Passing next to the parts above the lesion, we find in the upper Pons that the Posterior Longitudinal Bundle of the left side is deeply degenerated, while the right one shows but little change; a few scattered fibres, however, lying lateral and slightly dorsal to it. (Plate VIII, Fig.3.)

On reaching the Posterior Corpora Quadrigemina the degeneration is still found almost wholly in the left bundle, but a few altered fibres are seen in the right also. The Fourth Nucleus appears in this series and the close relationship of the Posterior Longitudinal Bundle to this is well seen, many entering fibres passing to the cells of this on the left side. At a slightly anterior level the Third Nucleus begins to appear, and the very intimate connections of the Posterior Longitudinal Bundle to this can be noted, the left Nucleus being thickly dotted with fine terminal degeneration. A few fibres are also seen entering the right Nucleus directly, while some appear to reach it by crossing from the left side. (Plate VIII, Fig.2).

Coming now to the Anterior Corpora Quadrigemina the long cell column of the Third Nucleus can still be followed, and the emerging fibres of the Third Nerve are seen passing downwards. There is still much degeneration in the left Nucleus, and many crossing fibres are seen passing through the

centrally placed Grey Matter. (Plate VIII, Fig.1.) About this level the degeneration begins rapidly to diminish in amount, and at the upper level of the Third Nucleus it is so reduced as to be practically terminal and its further tracing becomes a matter of great difficulty. The results of this case may be briefly recapitulated as follows :- A lesion practically limited to Deiters' Nucleus has produced a definite descending degeneration in the Cord, passing mainly by the Posterior Longitudinal Bundle but also by a special tract, and affecting both sides but chiefly the right, in which it is traceable to the Lumbar region; also an ascending degeneration can be followed above the level of the lesion in the Posterior Longitudinal Bundle of the left side as far as the upper limits of the Third Nucleus, in which or in the "Oberer Oculomotoriuskern" it appears to terminate. The striking feature is the large share taken by fibres derived from one Deiters' Nucleus in the formation of the Posterior Longitudinal Bundle of the opposite side above the level of the Nucleus and of the same side below this level, while relatively few fibres pass up in the bundle of the same, or down in that of the opposite side; this seems against the view that the fibres from Deiters' Nucleus divide on entering the Posterior Longitudinal Bundle into ascending

and descending branches as, if that were the case, one would expect to meet with equal degeneration in both directions, probably then different sets of fibres pass, the one up and the other down in the bundle.

Turning now to the more complicated degeneration in Monkey III, here a similar operation was performed, but the after-results indicated a wider damage than usual. The day after the operation the animal was found to have taken up a very characteristic attitude, the head being depressed to the right side and rotated so that the face looked towards the left; the eyes showed marked and irregular Nystagmus; there was no squint nor inequality of the pupils. When taken out of its cage, the animal tended to perform "Compass" movements", turning constantly round a vertical axis from right to left; also if sitting up without support it tended to fall backwards and to the right, and had some little difficulty in regaining its balance. All these symptoms tended to diminish, the Nystagmus disappeared at the end of 4 days and after the elapse of a week the tendency to fall had almost gone and the "compass movements" were much less marked. There was at no time any paralysis of motion, or sensation, the response to touch or prick being sharp. The position of the head

Fig 1.(MIII 3(26)).

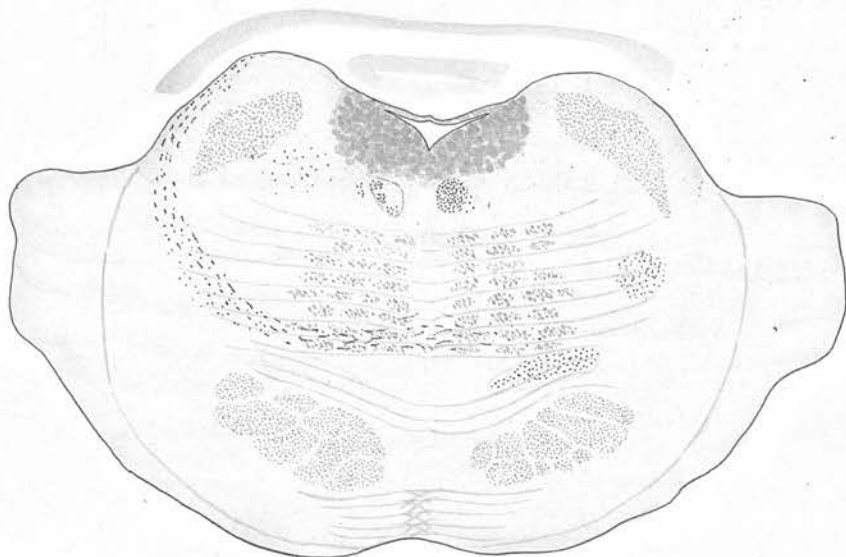


Fig 2.(MIII.3(5)).

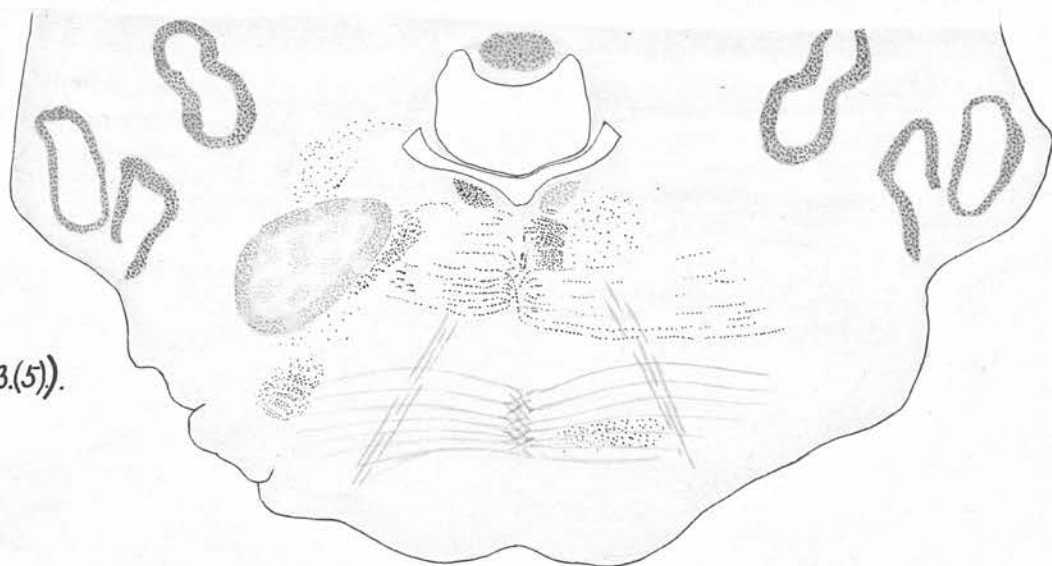
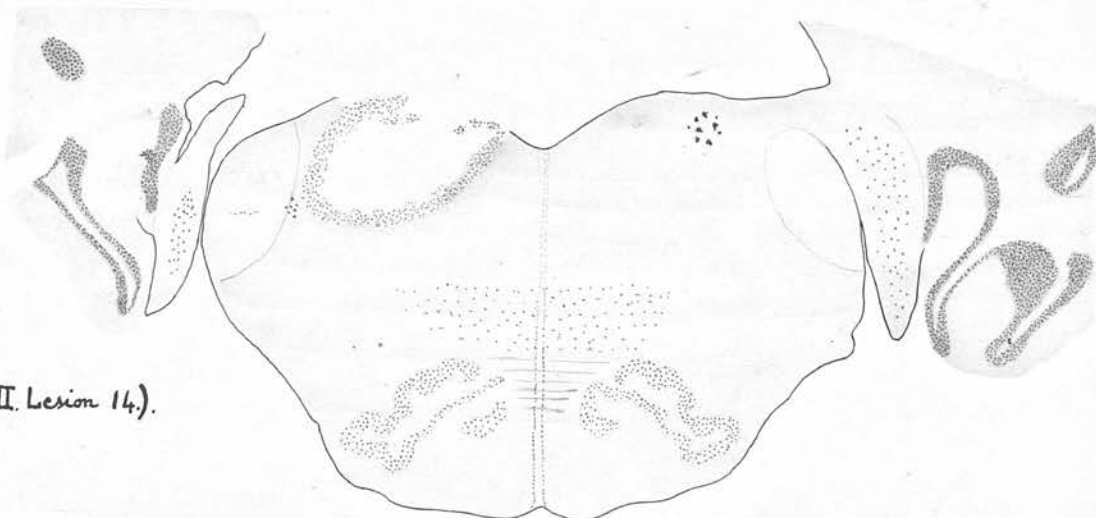


Fig. 3.(MIII. Lesion 14.).



persisted, and it should perhaps be said that there was no greater damage to the neck muscles in this case than in any of the preceding. The animal was allowed to live 18 days and then killed by chloroform, and the Brain and Cord prepared in the usual way, the upper Medulla being hardened in Formal and the remainder in Muller's Fluid.

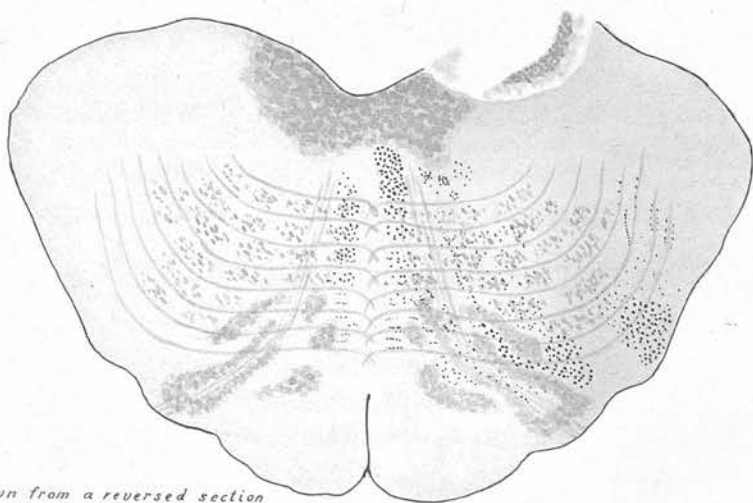
The lesion here was found to be much more wide-spread than in the preceding case. In the upper Medulla and lower Pons, which have been stained with Toluidin blue, it appears as an obliquely directly somewhat oval area lying in the lateral part of the floor of the Ventricle and extending to a depth of from 1 - 2 m.m., increasing in depth anteriorly, while getting more superficial posteriorly. It is obvious from the anterior sections of this series that Deiters' Nucleus has been destroyed, although unfortunately the tissue "cut out" just as the level of this was reached, still the large cells of the Nucleus are easily seen lying in the margin of the left side of the section at a corresponding point to that occupied by the lesion on the right. In no place does the lesion touch the Posterior Longitudinal Bundle itself which is quite intact throughout. (Plate IX, Fig3.)

On tracing the lesion forwards into the Pons, which has been stained by Marchi's method it is

seen as a large area of granular debris oval in shape and oblique in direction lying along the course of the Seventh Nerve which it has cut across. The Sixth Nucleus is quite intact and the emerging nerve undegenerated. In anterior part of the Pons the lesion rapidly diminishes in size and has disappeared in the upper sections. From the site lesion numerous degenerated fibres are seen passing in long curves across to the opposite side to enter the Posterior Longitudinal Bundle, in which they turn in a vertical direction. All these Arcuate fibres, however, do not enter the bundle, some pass onwards into the Formatio Reticularis of the left side and appear to terminate in relation to the Superior Olive. On the same side as the lesion many fibres are seen passing upwards in the Cerebellar Peduncle, while a special collection of transversely cut fibres is to be noted as lying between the lower part of the lesion and the Corpus Trapezoides. (Plate IX, Fig.2.)

Turning now to the lower Medulla there is in the upper part of this series a slight trace of the lesion affecting the posterior columns, so that a few Arcuate fibres sweep across towards the left Fillet. In addition to these other and much better marked areas of degeneration are to be noted. In the first place both Posterior Longitudinal Bundles

reversed



Drawn from a reversed section

Fig 1. (M. III. 4(7)).

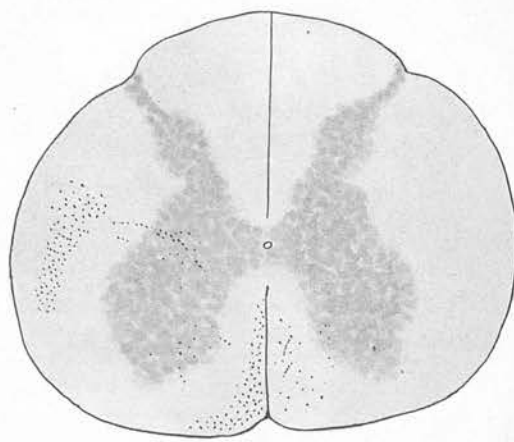


Fig 4. (M. III. 7(6)).

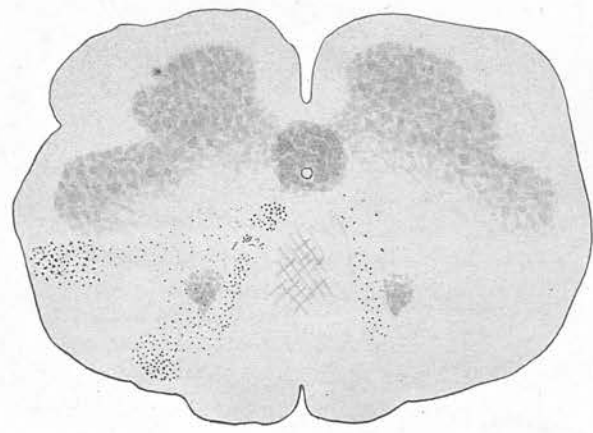


Fig 2. (M. III. 5(8)).

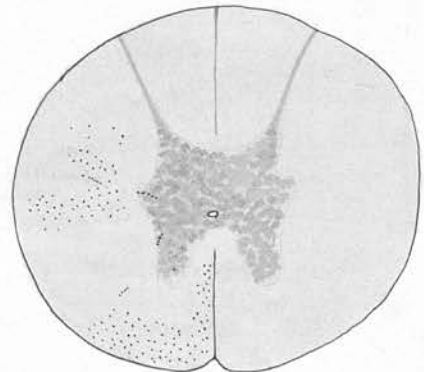


Fig 5. (M. III. 8(2)).

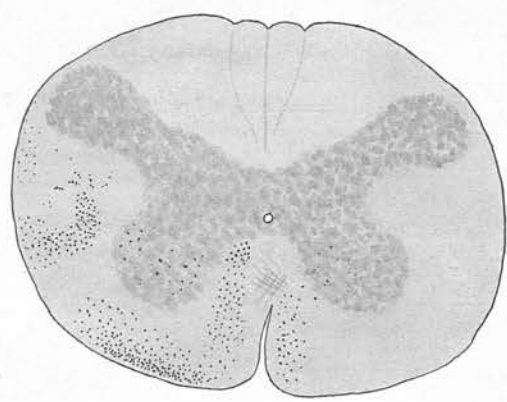


Fig 3. (M. III. 6(3)).

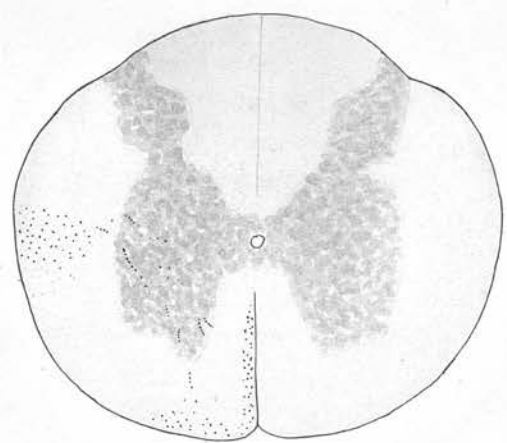


Fig 6. (M. III. 9(2)).

are affected; the right very markedly, the left to a lesser extent; then a degenerated strand is seen lying Dorso-lateral to the Inferior Olive of the right side in the region already noted as containing the direct spinal fibres from Deiters' Nucleus. These are seen passing through the Formatio Reticularis to reach this strand. But there is yet a third region of degeneration of special interest. It lies close along the margin of the Medulla dorsal to that just mentioned from which it is separated by an area clear of degeneration. It extends to just ventral of the Substantia Gelatinosa. This strand can be traced into continuity with that noted in Plate IX, Fig.2.) as lying immediately below the lesion. It has not been found degenerated in any of the preceding animals. (Plate X, Fig.1.)

In the "closed" Medulla the right Posterior Longitudinal Bundle extends as an unbroken black strand from just below the central Grey Matter to near the anterior margin of the Cord; the left bundle shows degeneration in the part corresponding to the more ventral portion of this. The direct tract from Deiters' Nucleus is found compacted now into a definite bundle just anterior to the commencing Anterior Horn, while Dorsal and Lateral to this lies the Third degenerated strand which is also getting more sharply circumscribed. (Plate X, Fig.2.)

The decussation of the Pyramids begins in this series. In the first Cervical segment, in which the transition from Medulla to Cervical Cord is seen, the degenerated fibres undergo a change of arrangement. On the left side a small area of degeneration lying lateral to the Median Fissure represents the downwards continuation of the left Posterior Longitudinal Bundle. On the right side a much wider spread of degeneration appears lying not only along the Fissure but extending also in a lateral direction along the very margin of the Cord. This is really composed of two fused strands, the right Posterior Longitudinal Bundle and the direct strand from Deiters' Nucleus; it is this latter which causes the marked peripheral degeneration. There is still a third degenerated area to note; this lies in the position that the posterior part of Löwenthal's tract would occupy, but is separated from the anterior degeneration by a region of normal fibres. This lateral degeneration is somewhat crescentic as seen in transverse sections, the concavity of the present looking backwards. There appears to be little, if any, encroachment on the region of the Crossed Pyramidal Tract. (Plate X, Fig.3.)

Turning next to Mid Cervical Cord, the Antero-Lateral degeneration is found to be limited almost

wholly to the right side, a few scattered fibres only appearing to the left of the Anterior Fissure. The degenerated tract in the Lateral Column is quite isolated from the more anterior degeneration and from both of these entering fibres can be traced to the Grey Matter. The fibres given off from the Antero-Lateral area appear to end around the large Anterior Horn cells which constitute the mesial group. Those from the Lateral tract enter about the middle of the lateral aspect of the Horn and are distinctly traceable for some distance sweeping somewhat forward in their course and ending apparently by breaking up into fine fibrils around the more posterior and lateral nerve cells in this position. (Plate X, Fig.4.)

Turning next to the Mid Dorsal Cord, it is found that the anterior degeneration has spread somewhat along the margin of the Cord, but still fails to reach the lateral column which is less well marked here, its fibres being more scattered. Entering fibres to the Grey Matter are few here. (Plate X, Fig. 5.)

On reaching the Lumbar Cord both the areas of degeneration are somewhat reduced in size. From the Antero-Lateral Columns degenerated fibres can easily be traced to the Anterior Horn cells. The lateral column degeneration has now come to lie

on the surface of the Cord from which it was separated by undegenerated fibres at the higher levels. It also still furnishes numerous fibres to the Grey Matter which appear to end amongst the more lateral cells, none reaching either the Motor cells or those of Clarke's Column in the Posterior Horn. Some obliquely cut vertical sections in this region show these entering fibres well. (Plate X, Fig.6.)

Turning now to the parts above the lesion, we find in the most anterior part of the Pons well-marked degeneration of the left Posterior Longitudinal Bundle, a few fibres appearing in the right also. The left Fillet shows marked degeneration, and Arcuate fibres are seen crossing in the Raphe and leading up on the right side to pass dorsal to the Superior Cerebellar Peduncle. A few degenerated fibres also lie in the position of the lateral Fillet on the left side. (Plate IX, Fig.1.)

On reaching the Posterior Corpora Quadrigemina the same appearances hold. With regard to the Posterior Longitudinal Bundles, the degeneration is thickest in the more mesial parts of the left and the more lateral part of the right. Fibres are traceable to the Third Nucleus in the anterior part of this series.

In the region of the Anterior Corpora Quadrigemina the degeneration is much reduced, but still

shows fairly clearly to the left of the Third Nucleus, and a few scattered fibres appear to the right of this. There is much terminal degeneration in the Nucleus, derived from the left bundle. Beyond this level the degeneration, except in the Fillet, cannot be traced with certainty.

To summarise this case:- The Cord degeneration is that resulting on damage to Deiters' Nucleus complicated by the presence of a tract of descending degeneration situated in the lateral column ventral in position to the Crossed Pyramidal Tract. The entering fibres to the central Grey Matter from this are of much interest. The upward spread of degeneration here is similar to that met with in the former case, the marked degeneration of the Posterior Longitudinal Bundle of the opposite side to the lesion in its more mesial part being the chief feature to note.

We now reach the third and last group into which the position of the lesion divides the animals operated on. This group includes those in which the injury has affected neither the Posterior Longitudinal Bundle nor Deiters' Nucleus directly, but has fallen somewhere between these in the lateral part of the floor of the Fourth Ventricle. This class again consists of two animals (both Monkeys) in one of which (M.II) the lesion is again comparatively limited, while in the other (M.VI) it is

much more wide spread.

Turning first to Monkey II, the operation was performed in the usual way, and the animal quickly recovered and showed but little evidence of lesion. There was again Nystagmus persisting for a few days and then gradually passing off. This was the only eye change. As regards Motor and Sensory conditions nothing abnormal was to be noted. The animal was killed on the sixteenth day after the operation, and the Brain and Cord prepared by Marchi's method, with the exception of the upper Medulla which was stained with Töluidin blue. On examination the lesion was found to be more extensive than naked eye inspection had suggested, the Cautery having produced a tunnelled area of destruction below the level of the floor of the upper part of the Fourth Ventricle, while the visible lesion in upper Medulla is comparatively superficial. The anterior portion of the lesion has destroyed the Sixth Nucleus and cut across the Seventh Nerve, so that both the Sixth and Seventh Nerves appear degenerated. The area of degeneration lies between the blackened strands of these two nerve trunks. From its position it has effectually cut the fibres passing from the right Deiters' Nucleus to the Posterior Longitudinal Bundles without damaging the Cerebellar Peduncle. The direct

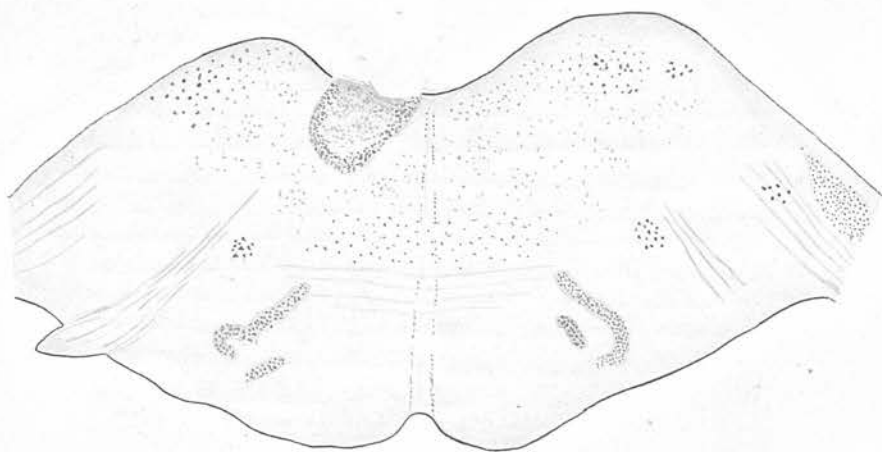


Fig 1. (MII. Lesion q).

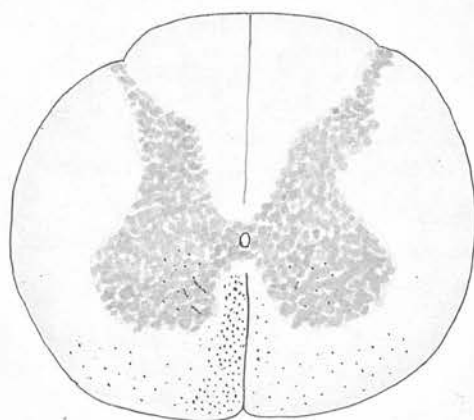


Fig 4 (MII. $\gamma(1)$).

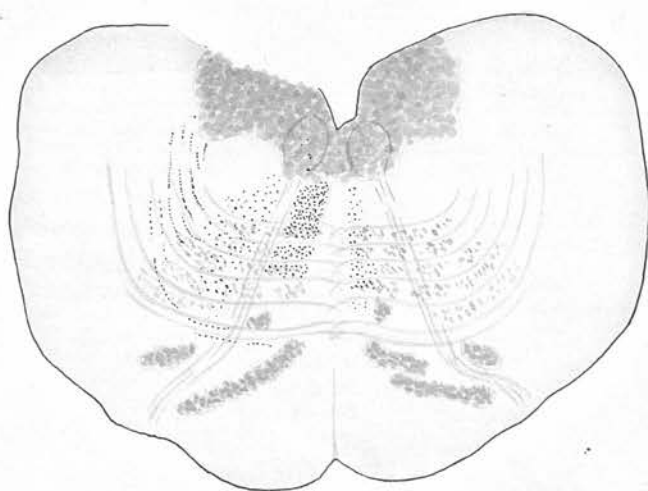


Fig 2. (MII. 6(5)).

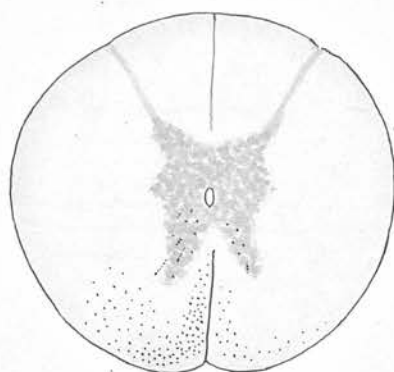


Fig 5. (MII 8(2)).

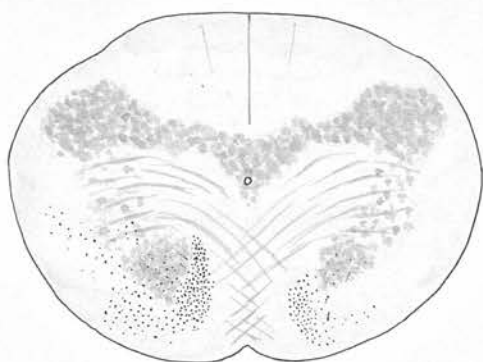


Fig 3. (MII. 6^a(8)).

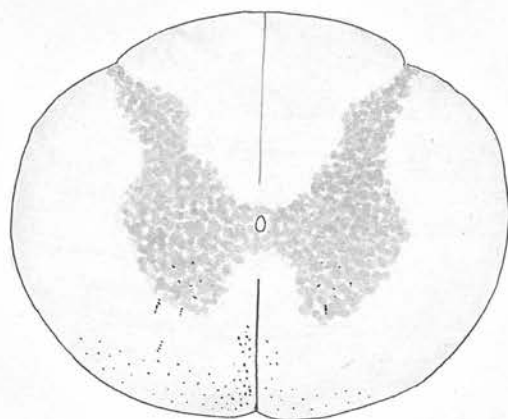


Fig 6. (MII. q(2)).

spinal tract from this Nucleus has escaped injury. Degenerated fibres are seen passing in considerable numbers through the Raphe to enter the Posterior Longitudinal Bundle on the left side. Some, however bend away from this and appear to pass towards the Superior Olive, yet others go to end in the Formatio Reticularis of the left side, and a few appear to have the same termination on the right. (Plate XII, Fig.3.)

In the lower part of its extent the lesion appears to have very slightly encroached on the more superficial part of the right Posterior Longitudinal Bundle in the upper Medulla. (Plate XI, Fig.1.)

Turning next to the parts below the lesion, we find in the lower Medulla a faint trace of injury to the right Posterior Column Nuclei, so that a few Arcuate fibres are degenerated. This section falls through the Twelfth Nuclei and shows the emerging fibres of the Hypoglossal Nerves which serve to limit the lateral spread of the definite degeneration which affects both Posterior Longitudinal Bundles, the right in its whole vertical extent, the left in its more ventral part; but there is also a good deal of scattered degeneration in the Formatio Reticularis lateral to the right bundle. There is some evidence of degenerated fibres in

the Twelfth Nucleus of the right side also. (Plate XI, Fig.2.)

On reaching the Decussation of the Pyramids a very definite degeneration is seen encircling the commencement of the Anterior Horn on the right side, to which it gives many fine fibres; a similar but much slighter degeneration shows on the left side. The crossing bundles of the pyramidal fibres intervene between these two areas. (Plate XI, Fig.3.) In the Mid Cervical region the right side of the Anterior Median Fissure is black with degeneration, this spreads out round the Anterior Horn, to which many fibres pass, and extends as a more scattered area laterally in the Anterior Column. On the left side the degeneration alongside the Anterior Fissure is only slight and does not show so marked a lateral spread as on the right. (Plate XI, Fig.4.)

Passing next to the Mid Dorsal region the right sided degeneration is seen to have become more diffuse, but is gathered into a fairly definite strand at the periphery of the Antero-Lateral Columns. The degeneration does not extend the whole length of the Anterior Fissure. On the left side the degeneration is very small in amount, but lies scattered in a similar region of the Cord. (Plate XI, Fig. 5.)

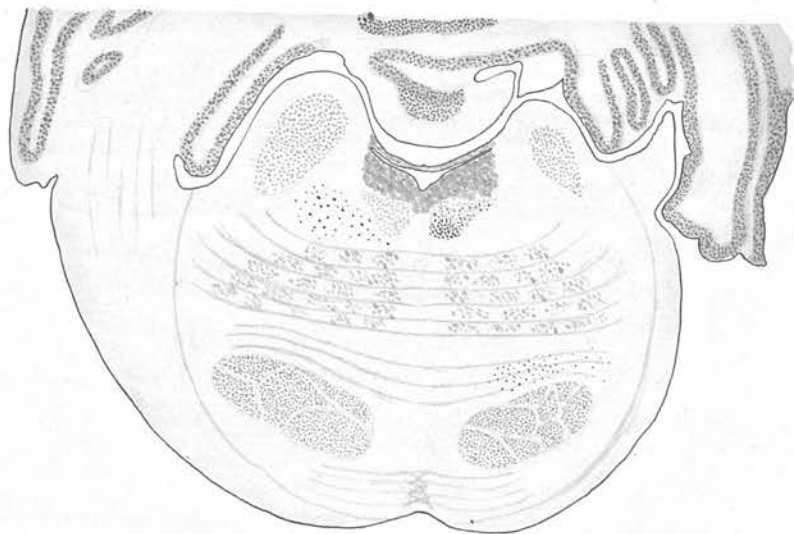


Fig 1. (MII. 4. (13) & (6)).

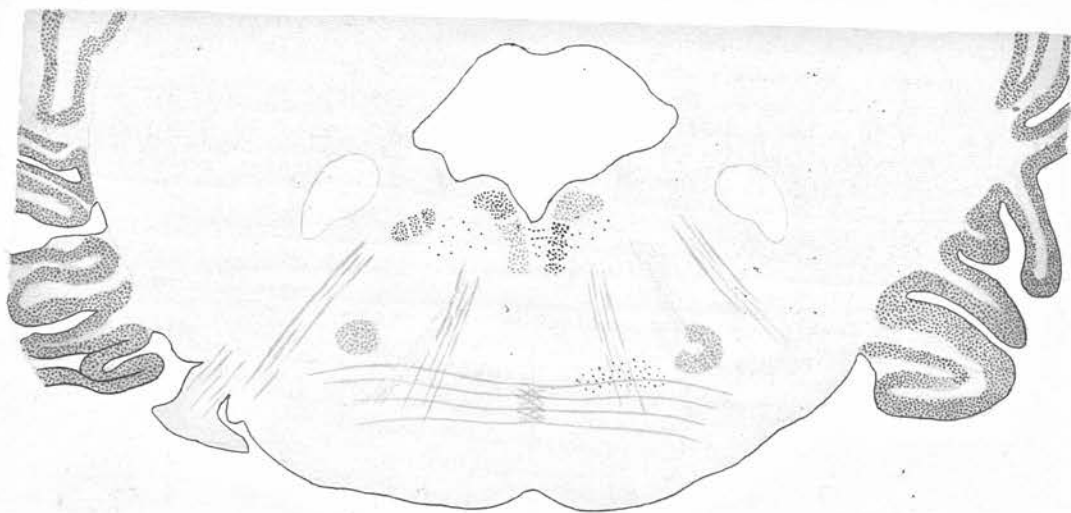


Fig 2. (MII. 5 (6)).

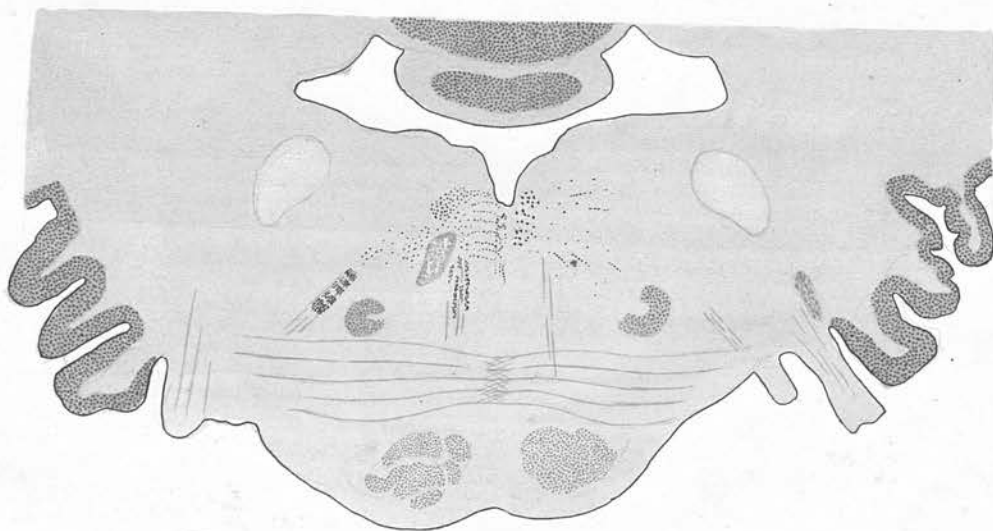


Fig 3. (MII. 5. (16)).

Finally, in the region of the Lumbar Cord we find a reduced but still well marked right-sided degeneration, the fibres of which are grouped much more definitely again in a peripheral strand. It is noticeable that the degeneration lateral to the Anterior Median Fissure does not now extend more than half way towards the Anterior Commissure. On the left side a few degenerated fibres still show and fine degeneration can still be traced in both Anterior Horns. (Plate XI, Fig.6.)

Turning next to the series above the lesion, we find in the upper Pons marked degeneration of the Posterior Longitudinal Bundle of the left side. That of the right is clear of degeneration, except for fibres passing through it to the left side. The Sixth and Seventh Nerves still show damaged fibres. (Plate XII, Fig.3.) On reaching the highest part of the Pons the left bundle shows distinctly, while here the Sixth and Seventh Nerves show undegenerated, the whole of their Nuclei then have not been destroyed. A slight amount of Fillet degeneration is to be noted on the left side. (Plate XII, Fig.2.) In the most anterior sections of this region the left Posterior Longitudinal Bundle stands out distinctly as a rounded black strand. The degeneration is especially marked in the more ventral

Fig. 1. (MII. 2(1)).

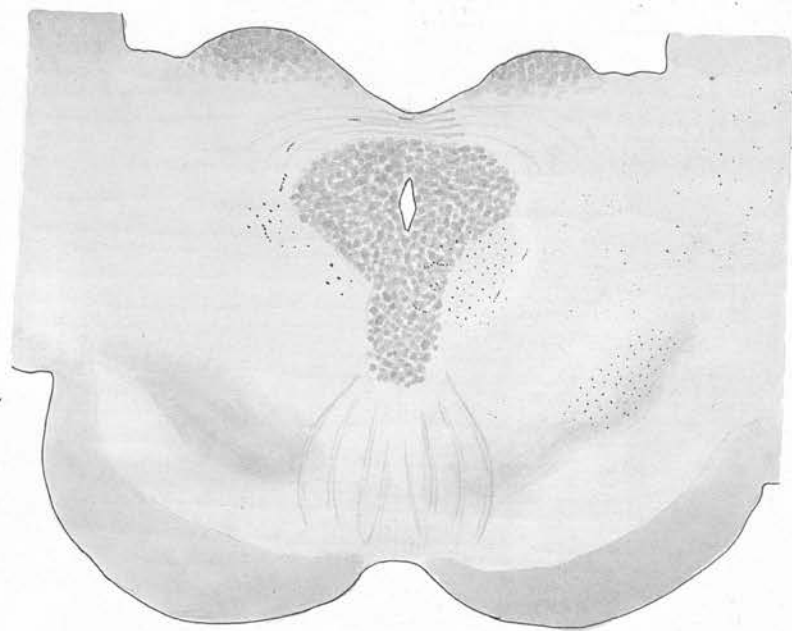


Fig. 2. (MII. 2(11) & (10)).

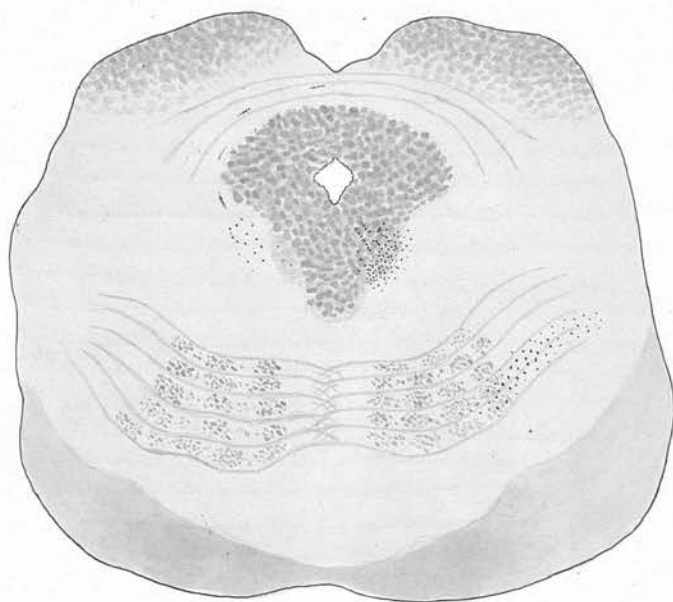
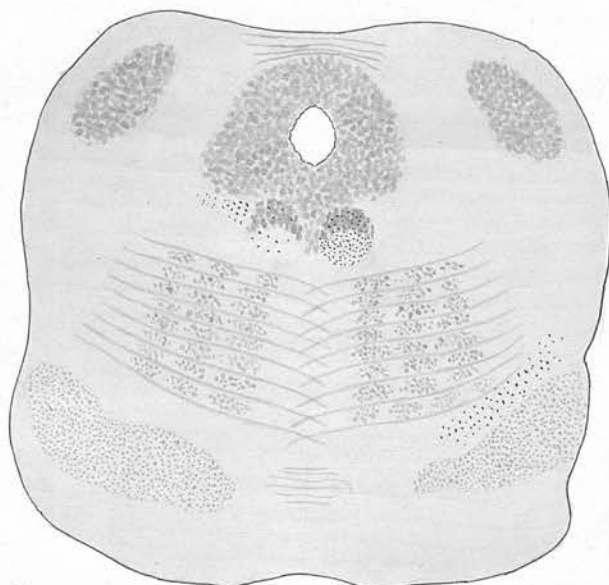


Fig. 3. (MII. 3(2) & (9)).



parts, less so laterally and dorsally. There are some degenerated fibres in the *Formatio Reticularis* on both sides lateral to the Posterior Longitudinal Bundles. (Plate XII, Fig.1.)

Passing next to the Posterior Corpora Quadrigemina, the left bundle still shows deeply stained; a few degenerated fibres are to be seen in the right bundle also. The degeneration in the left Fillet is leading away outwards and upwards. The Third Nucleus begins to appear in the anterior sections of this region and on the left side is studded with fine degeneration. There are also blackened fibres lateral to the right bundle. (Plate XIII, Fig.3.)

On reaching the Anterior Corpora Quadrigemina the V shaped mass of Grey Matter forming the Third Nucleus is seen limited by the laterally placed Posterior Longitudinal Bundles, from the left one of which numerous blackened fibres pass in to end round the nerve cells of this Nucleus, some passing across the middle line. Also in this section some of the degenerated fibres in the *Formatio Reticularis* which have been previously cut transversely are seen changing their direction, and now appear in almost longitudinal section; sweeping up round the central Grey Matter apparently towards the Posterior Commissure. (Plate XIII, Fig.2.) In the more anterior sections of this part there is still

indication of the position of the left bundle, but the degeneration gets so faint after this level that it cannot definitely be followed further, although some scattered fibres appear in the Subthalamie region. The Fillet degeneration is still to be seen, and can be traced to the Optic Thalamas. (Plate XIII, Fig.1.)

To sum up, the injury may be said to consist here of a severance of those fibres from Deiters' Nucleus which pass to the Posterior Longitudinal Bundle with considerable damage to the Sixth and Seventh Nuclei and possibly a very slight injury to the right Posterior Longitudinal Bundle itself in the lower part of its course. As the result there is marked degeneration, right-sided in the Cord, and left-sided in the Brain above the lesion. There is some indication of fibres passing across in the Posterior Commissure here, so that possibly some of the ascending fibres do pass directly through this to connect with the Ganglia of the opposite side; but the majority of these crossing fibres (which are only very few in number) appear to come from the degeneration noted as lying lateral to the Posterior Longitudinal Bundle.

Taking up now the examination of the material furnished by Monkey VI, in which a similar operation was performed, we find the lesion to be wide spread.

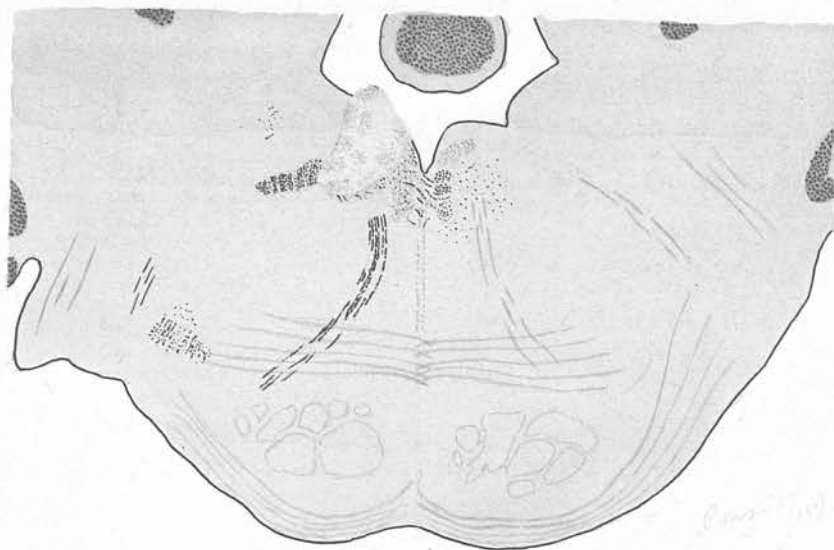


Fig. 1. (M.VI. 7. (15)).

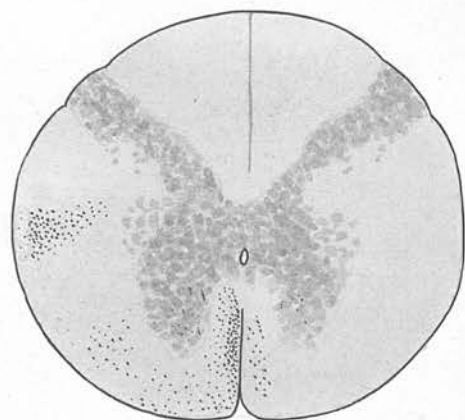


Fig. 4. (M.VI. 12. (3)).

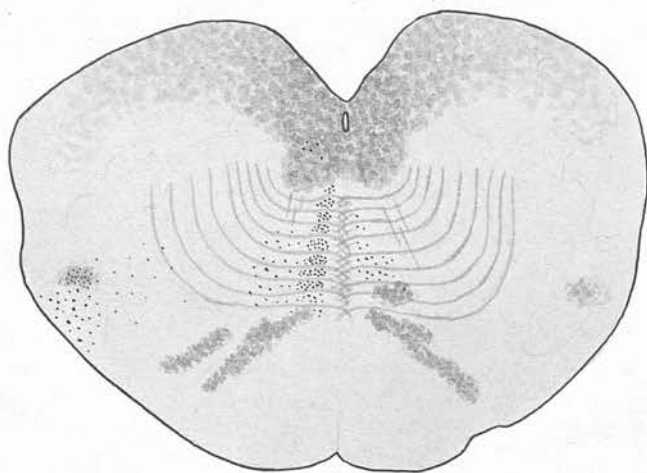


Fig. 2. (M.VI. 9. (2)).

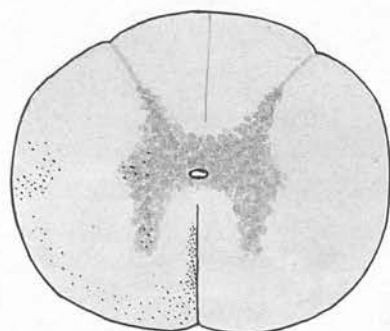


Fig. 5. (M.VI. 13. (5)).

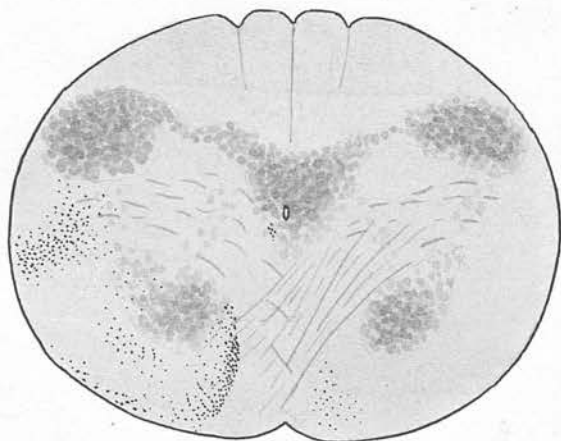


Fig. 3. (M.VI. 11. (1)).

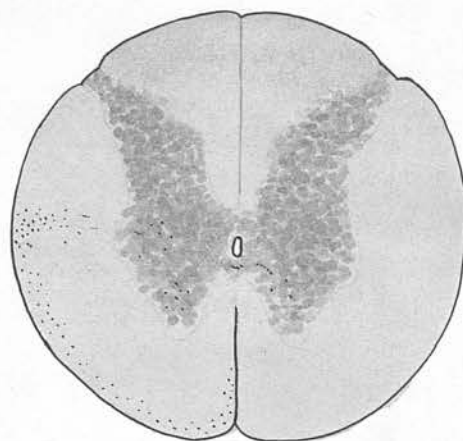


Fig. 6. (M.VI. 14. (2)).

It is met with as a comparatively superficial area in the lower part of the Pons, but extends anterior to this getting deeper and more lateral in position until it ends in the region of the Posterior Corpora Quadrigemina in the posterior part of the Tegmentum, just dorsal to the Fillet as this bends up in its lateral course. The Fillet is cut across just at this point by the most anterior part of the lesion, and so shows degeneration in its further course. The lower portion of the lesion appears as a wedge-shaped area of blackened debris, extending from 1-2 m.m. below the floor of the Fourth Ventricle. It cuts across the Genu of the Facial Nerve and destroys the Nucleus of the Sixth Nerve, so that both these nerve trunks appear in these preparations stained black. Many degenerated fibres pass across in the Raphe to end either in the opposite (left) Posterior Longitudinal Bundle or in the Sixth Nucleus. There is still one other collection of altered fibres to be noticed; this is found on the same side as the lesion situated between the Sixth and Seventh Nerves, just dorsal to the position of the Superior Olive. It appears as an irregularly circular strand as seen in transverse sections. (Plate XIV, Fig.1.)

Passing now to the parts below the lesion, in the Medulla both Posterior Longitudinal Bundles

are found to show degeneration, but this is much more marked on the right side, on which also there is a small amount of degeneration in the *Formatio Reticularis* lateral to the bundle. This in all probability is due to some damage to the direct spinal tract from *Deiters' Nucleus*. A lateral area of degeneration is also seen here, closely associated with the lateral *Nucleus*, to which it appears to give fibres, as much very fine degeneration can be traced amongst the cells of this *Nucleus*. This laterally placed strand is continuous with that noted in the lower Pons. (Plate XIV, Fig.2.). In the lower part of the Medulla at the level of the Twelfth *Nucleus*, the lateral strand is nearing the surface, many of its fibres being cut obliquely or almost longitudinally here. Some fine degeneration can be seen in the *Hypoglossal Nucleus*.

At the level of the Decussation of the *Pyramids* the two degenerated strands continuing the *Posterior Longitudinal Bundles* intervene between the *Grey Matter* of the *Anterior Horns* and the area of crossing fibres. The greater amount of degeneration on the right side is now clearly shown. It extends from just below the central canal to the outer aspect of the *Anterior Horn* where it tends to show a division into two strands, one closely applied to the periphery of the Cord, the other in immediate

relationship to the Grey Matter. The lateral tract is now very well seen lying close to the surface. Towards the lower end of the pyramidal decussation the fusion between the Posterior Longitudinal Bundle fibres and those from the direct tract of Deiters' Nucleus is well seen, the latter constituting the more peripheral portion of the degeneration. (Plate XIV, Fig.3.)

Passing on to the upper Cervical Cord, degeneration is found on both sides of the Anterior Median Fissure; it is restricted to this position on the left side. On the right, not only is it denser in the corresponding part, but spreads out laterally far round the Anterior Horn, falling short however of the lateral tract of degeneration, which seems to be spreading somewhat forwards in this region. Much fine degeneration is visible in the Anterior Horns now especially round the more median group of cells; the entering fibres from the anterior area of degeneration can be clearly traced to these. Here, too, the lateral tract begins to give off fibres which are traceable to the lateral part of the Grey Matter. In the Mid Cervical Cord the anterior and lateral parts of the degeneration almost unite so that a typical Löwenthal's tract results. The anterior and posterior extremities are thick and well marked. The middle portion

consists only of a thin strand of scattered fibres. Entering fibres to the lateral region of the Grey Matter are now well seen from the lateral tract. (Plate XIV, Fig. 4.)

Descending to the Mid Dorsal region, the left side is found quite clear of degeneration, but on the right a scattered area is seen most marked alongside the Anterior Median Fissure and in the region of the lateral tract. Degeneration is slightly marked in both anterior and lateral parts of the Grey Matter. (Plate XIV, Fig.5.)

On reaching the Lumbar region, the amount of degeneration has greatly diminished, and forms now a long narrow peripheral tract. There is much fine degeneration again in the central Grey Matter, especially around the mesial group of Anterior Horn cells. Entering fibres to this region are seen from the anterior part of the degenerated zone, while from the posterior part of this (i.e. the continuation of the lateral part) many fibres pass to end around cells in the lateral part of the Grey Matter, none apparently passing to Clarke's Column, which is seen at the base of the Posterior Horn . (Plate XIV, Fig.6.)

Passing now to the part above the lesion, in the hindmost part of the Posterior Corpora Quadrigemina there is still a trace of the lesion, which is

Fig 1. (M.VI 5(10)).

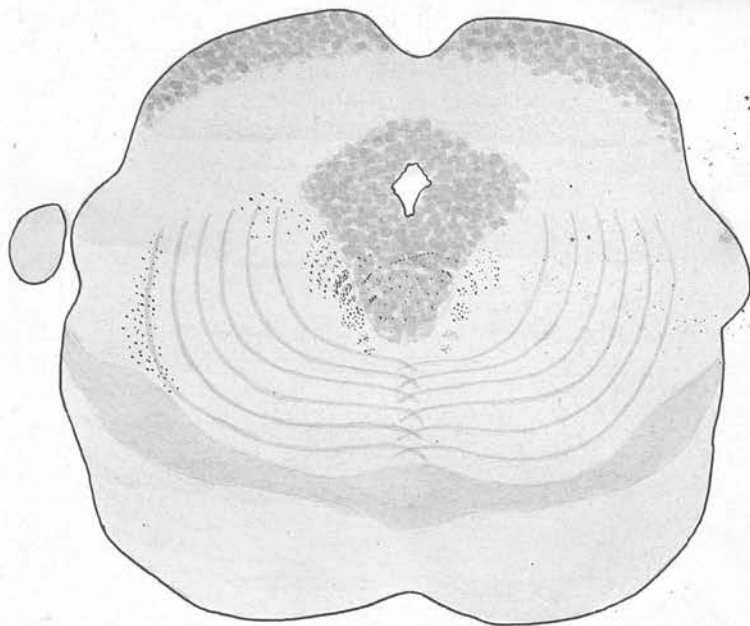


Fig 2. (M.VI 6(11)&(4)).

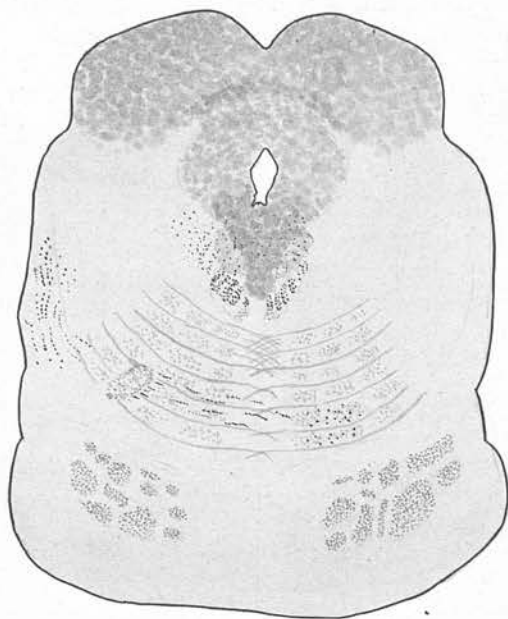
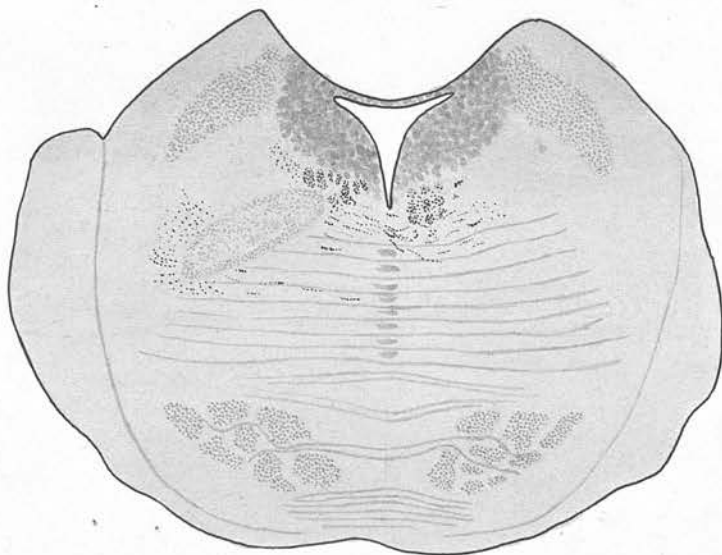


Fig 3. (M.VI 7(3)).



seen cutting the most internal part of the lateral Fillet, so that the dorsal portion of this is degenerated; also from the site of the lesion a few fibres are seen crossing through the Raphe to the opposite side, where they seem to lose themselves. Both Posterior Longitudinal Bundles are deeply degenerated, almost equally so. They give off fibres to the Fourth Nucleus, and in the higher parts to the Third Nucleus which begins to appear here. (Plate XV, fig.2.)

Passing further forwards to the Anterior Corpora Quadrigemina, there is marked degeneration of the lateral Fillet due to the injury noted above. The Posterior Longitudinal Bundle degeneration is getting less, but a few black lines suggest fibres quitting it and passing outwards towards the Optic Thalamus. The emerging roots of the Third Nerve are seen quite free from degeneration (Pl. XV. Fig.1)

The results in this case, then, depend on a division of the fibres from Deiters' Nucleus, together with the destruction of the Sixth Nucleus, the injury to which probably accounts for the increased amount of degeneration in the right Posterior Longitudinal Bundle above the lesion in this case. The lateral column tract is again found degenerated here, and is traceable further forwards than in the former case in which it is noted (Monkey III). It seems to be associated with some

of the masses of Grey Matter which lie in the posterior part of the ~~Mid Brain~~ in the vicinity of the ~~Posterior~~ Corpora Quadrigemina.

Coming now to a comparison of the results obtained in these various groups, some points of great interest arise. The intimate relationship of the anterior continuation of the Posterior Longitudinal Bundle to the Nuclei of the Ocular Muscles which has been noted by many former observers, is amply confirmed in these cases. In every case in which the bundle was cut anterior to the point of entrance of fibres from Deiters' Nucleus, there was profound degeneration traceable to these Nuclei; but it is noteworthy that if the lesion fell ever so little below this level no such change occurred. About the question of the passage of direct fibres from the Posterior Longitudinal Bundle into the Ocular Nerve trunks, a few words must be said:- This passage was first stated to occur by Duval and Laborde, and was reaffirmed as recently as 1898 by Gee and Tooth, a similar relationship of the Seventh Nerve having been noted by Tooth and Turner. The material examined and described above does not tend to support this view. In several cases the Sixth Nucleus was either destroyed or severely injured, so that if the theory which ascribes to this Nucleus

the supply of fibres to both the Third and Fourth Nerves were correct degeneration should have been marked in these trunks. In no case was degeneration of the Third Nerve ever met with, and only one section out of the hundreds examined did a fibre appear to reach the Fourth Nerve from the Posterior Longitudinal Bundle, and in this case the Sixth Nucleus was uninjured. It is important to note that an irregular granular deposit does not constitute degeneration, as this is often met with in the issuing nerve roots, both in Brain and Spinal Cord, after the use of Marchi's method; Professor Schäfer has suggested that this may be due to the action of leucocytes removing degenerated fatty material along the lymph channels, the hardening process fixing this so that it is subsequently stained by the Osmic Acid solution. But if fibres are not traceable to the nerve trunk, there can be no doubt as to the passage of these to the Ocular Nuclei from the Posterior Longitudinal Bundle. In all cases in which the lesion fell in the upper part of the floor of the Fourth Ventricle, there was marked fine degeneration around the cells of these Nuclei, and this occurred whether the lesion affected the Posterior Longitudinal Bundle itself or the Sixth Nucleus or, and this is noteworthy, Deiters' Nucleus alone. In this relation the conditions met with in

Monkey VI are interesting. Here the Sixth Nucleus is destroyed, and the lesion at the same time cuts across the fibres which pass from Deiters' Nucleus to the opposite Posterior Longitudinal Bundle, both Posterior Longitudinal Bundles are found markedly degenerated anterior to the lesion, and much fine degeneration occurs in the Fourth, and especially in the Third Nucleus. We have noted previously that Deiters' Nucleus furnishes ascending fibres almost wholly to the Posterior Longitudinal Bundle of the opposite side, so that in Monkey VI the degeneration in the Homolateral bundle must be ascribed, largely at least, to fibres passing up from the Sixth Nucleus.

Passing next to another generally accepted relationship of the Posterior Longitudinal Bundle, that to the Antero-lateral columns of the Cord. Much has already been written with regard to this, and both descending and ascending fibres have been described. Some light is thrown on this question on comparing the results noted above. In Monkeys VII and VIII the degeneration in the Cord is practically the same, and is almost equal in amount in the two sides. In these two cases the lesion was one by which both Posterior Longitudinal Bundles were cut, - in the lower Pons in Monkey VII, in the upper Medulla in Monkey VIII. If these results are compared with those obtained in Monkey VI (in

which Deiters' Nucleus is destroyed) or in Monkey II (in which the fibres from Deiters' Nucleus to the Posterior Longitudinal Bundle were cut) it will be found that the latter show a unilateral degeneration in the Cord which very closely resembles that met with on either side in the former cases. So, then, the conclusion is arrived at that a large part at least of the descending degeneration passing by the Posterior Longitudinal Bundles into the Cord is due to the injury of fibres derived from Deiters' Nucleus. In this relation it is interesting to compare Boyce's results after an injury to the Mid Brain between Anterior and Posterior Corpora Quadrigemina. He notes only a slight descending degeneration of the Posterior Longitudinal Bundle itself. With regard to the fibres which are said to ascend from the Cord along the Posterior Longitudinal Bundle, the results obtained above leave some doubt. Tschermak has definitely described and traced such ascending fibres from the cells in the Commissural group of the Anterior Horn through the anterior columns of the Cord to enter the Posterior Longitudinal Bundle in the Medulla and pass up in this to end partly in Darkschewitsch's Nucleus and partly to cross in the Posterior Commissure. But in Monkey VIII, Cat VIII and Cat VII, in which the Posterior Longitudinal Bundle was cut in the Medulla

hardly any ascending degeneration is to be noted, the ascending degeneration which does occur in one bundle in Monkey VIII is explained by the fact of the lesion extending below the surface of the lower Pons and there dividing fibres on their way from Deiters' Nucleus which are destined to ascend in the Posterior Longitudinal Bundle. In contrast with these, the profound ascending degeneration met with in Monkey VII is interesting, for here the lesion is slightly higher in position and affects the Pons rather than the Medulla. In other words, it has cut the Posterior Longitudinal Bundle after the entrance of the fibres from Deiters' Nucleus. It is of value to compare the ascending degeneration in this case with that which occurs when Deiters' Nucleus itself is injured, or when the fibres from it are cut (See groups II and III). In both of these the appearance in the Posterior Longitudinal Bundle of the side opposite to the lesion is practically the same as in Monkey VII, so that one is forced to the conclusion that apart from the fibres derived from Deiters' Nucleus, the Posterior Longitudinal Bundle does not contain many which ascend, with the exception, of course, of the short strands passing to it from the Sixth Nucleus.

The position of the lesion in the Posterior Longitudinal Bundle then determines the character

of the resulting degeneration. If the lesion is below the level of the entrance of the fibres from Deiters' Nucleus, there is only descending degeneration which is greater in amount than that which follows injury to Deiters' Nucleus itself owing to the admixture of fibres from other sources in the bundle at this level. But if the lesion is above the level of this entering strand, there is profound ascending degeneration, and this is practically the same in amount and appearance to that which results on destruction of Deiters' Nucleus itself. So it becomes obvious that the anterior part of the Posterior Longitudinal Bundle owes much of its importance to the fibres which it receives from Deiters' Nucleus while passing from the Medulla into the Pons.

It will be of interest, then, to turn for a little to the examination of this collection of nerve cells to which such frequent reference has been necessary in the foregoing description of the degeneration affecting the Posterior Longitudinal Bundle. This Nucleus has long been recognised, the large size of its cells making it a conspicuous object, Roller naming it "Nucleus magnocellularis" on this account. For a long time it was looked on as a Nucleus of the Auditory Nerve, being described

as the outer Nucleus by Clarke^{13.} in 1858. Deiters^{16.} (1866) was the first to cast doubt on this relation of the Nucleus. In his unfinished work on the Brain and Spinal Cord (collected and edited by Schwalbe) he denies the fact of its being an auditory nucleus, and speaks of it as a "way-station" situated between the tracts of the Spinal Cord and the Cerebellum. Stieda^{73.} (1870) again returned to the view that the Nucleus was related to the Auditory Nerve, indeed he refers to it as the "hauptkern" of this nerve, but since this date the view has steadily gained ground that this cell mass has other probably more important functions. Laura^{39.} in 1878 reaffirmed Deiters' view, and suggested the name by which this Nucleus is now generally known (Deiters' Nucleus). Von Monakow^{47.} (1883) was the next to investigate this Nucleus. He made a hemisection of the Cervical Cord in a one-day old rabbit which was allowed to live for several months, and then killed, and the Brain and Cord examined (Gudden's method of atrophy). Deiters' Nucleus was found degenerated on the side of the lesion. This Monakow¹ attributed to the injury to the Posterior Columns of the Cord and stated that Deiters' Nucleus was an "internode" on the sensory path to the Brain. A little later Vejas^{49.} (1885) specially investigated the relations of Funiculus Gracilis and Cuneatus to

Deiters' Nucleus. He cut across these Funiculi at the level of their Nuclei in a rabbit and allowed the animal to live 74 days, then killed it and examined the Medulla and Brain stained by the Carmine method. He got no sign of degeneration of Deiters' Nucleus, and so dissents from Monakow's view that this is related to the sensory strands. In the same year Onofrowicz^{51.} examined the brains of two rabbits in which the Auditory Nerve had been cut across some months before. He found no change in Deiters' Nucleus, so gives support to the view that this is not connected with the Auditory Nerve.

Bruce^{10.} (1889) in a paper dealing with the connections of the Inferior Olive, refers to Deiters' Nucleus as furnishing a strand of fibres to this. In 1890 Held, making use of Flechsig's embryological method traces two sorts of strands from Deiters' Nucleus to the Spinal Cord, one crossed, the other uncrossed. Blumeneau^{7.} (1891) tends to show that Monakow's original view with regard to a connection between the Posterior Column Nuclei and Deiters' Nucleus is to some extent correct. He shows that Collaterals are furnished to Deiters' Nucleus from the fibres passing to the Cerebellum from Nucleus

Cuneatus.^{11.} Bruce in 1892 inclines to the view that Bechterew's and Deiters' Nuclei are really different parts of one large Nucleus. Through Deiters' Nucleus

he recognises connection from the Vestibular Nerve to the opposite *Formatio Reticularis*, Posterior Longitudinal Bundle and Roof Nuclei of the Cerebellum. Ferrier and Turner²¹ (1894) in working at the Cerebellum, incidentally add much to our knowledge of Deiters' Nucleus; they absolutely failed to get the wide-spread Cord degeneration which Marchi had described after the removal of the Cerebellum, but they found that they could produce part of this degeneration by injuring Deiters' Nucleus, from which a descending tract passes into the Antero-Lateral columns of the Cord. In 1895 Turner⁴⁷ describes the passage of a strand of fibres from the Nuclei of the Roof in the Cerebellum to Deiters' Nucleus. He states that what used to be described as the cerebellar root of the Fifth Nerve is really formed by these fibres. Risien Russell⁵⁴ (1897) attacks the problem of the connections of Deiters' Nucleus in the Monkey, he was able by the use of a specially devised knife to cut out Deiters' Nucleus. Resulting on this lesion he describes both ascending and descending degeneration, the former passing by the Posterior Longitudinal Bundle "to the region of the Corpora Quadrigemina," the latter descending into the Cord partly through the Posterior Longitudinal Bundles, which Russell describes as equally degenerated, and partly by a direct tract which

joins the Posterior Longitudinal Bundle in the Cervical region to form an extensive Antero-Lateral degeneration in the Cord on the same side as the lesion. Sabin⁵⁷ (1897) gives an elaborate account of the relationships of the various Nuclei associated with the Eighth Nerve as seen in the Brain of the new-born child. Deiters' Nucleus (Nervi Vestibuli Lateralis) shows a sub-division into two parts, which however are joined by a region of more scattered cells. The Nucleus lies just at the point where the entering fibres of the Vestibular Nerve divide, and rests upon the upper end of the descending root while its sub-division into Pars Medialis and Lateralis is due to the passage up through it of the ascending fibres, from which many Collaterals are furnished to its cells. The large size of the cells mark out this Nucleus sharply from the other Vestibular Nuclei. In 1898 Thomas investigated the relationship of the Vestibular Nerve to Deiters' Nucleus, making use of Marchi's method. He divided the nerve intracranially in a dog which was allowed to live 15 days after the operation. Thomas⁷⁴ notes the division of the Vestibular Fibres into ascending and descending roots, and traces the former into close relationship with Deiters' and Bechterew's Nuclei. Tschermak⁶⁸ (1898) throws further light on the connection between

the Posterior Column Nuclei and Deiters' Nucleus, showing it to be more important than was previously supposed. He worked on cats, destroying the Nucleus Gracilis and Cuneatus, and recognises both a crossed and uncrossed connection to the Cerebellum from these, both of which paths furnish Collaterals to Deiters' Nucleus, so that this Nucleus may be influenced by impulses ascending from either side of the Spinal Cord. In 1900 Lloyd^{40.} examined the condition of Deiters' Nucleus in a series of Monkeys and Cats, in which Professor Schäfer had hemisected the Spinal Cord in the Cervical region. He made use of Nissl's method to determine any degeneration and found invariable and marked Chromatolysis of the cells of this Nucleus, such as occurs in cells whose axis cylinder processes have been injured. Sherrington^{60.} (1900) describes a tract in the Antero-Lateral column of the Cord derived from Deiters' Nucleus which he refers to as an end station for some of the Vestibular Nerve fibres. He says: "This bulbo-spinal system is in the main uncrossed and extends into the Lumbo-Sacral region running in the periphery of the Cord in the zone of emergence of the anterior nerve roots."

The preceding are merely a few references taken from the great mass of literature dealing with

Deiters' Nucleus, but they are sufficient to show how far-reaching are the connections of this cell station. The view originally put forward by Monakow that it is related to the sensory strands of the Cord is now amply confirmed by Blumeneau and Tschermak; the important relations of the Vestibular Nerve to this Nucleus are now clearly defined by Sabin and Thomas; while its double relationship to the Cerebellum has been described by Bruce and Turner. . . . So we have here a collection of cells which can be acted on by incoming influences either ascending from the Spinal Cord; or reaching it along that most important nerve of special sense, the vestibular part of the Eighth; while it is further under the direct control of the Cerebellum.

Having thus briefly noted these important relations of Deiters' Nucleus, let us turn again to consider the connection between it and the Posterior Longitudinal Bundle. We have already seen that the degeneration in the Cord resulting on a lesion of the Posterior Longitudinal Bundle in the upper Medulla, is closely imitated by that following destruction of Deiters' Nucleus; while the ascending degeneration resulting on an injury of the bundle in the lower Pons is also almost exactly reproduced by that following damage to this Nucleus; there is undoubtedly a greater difference in the former

than in the latter cases; but that is to be explained by the fact that in cutting across the Posterior Longitudinal Bundle itself, fibres are divided which have come from higher levels in the Brain. In other words, many fibres passing to the Ocular Nuclei above and to the Spinal Cord Ganglion cells below have their origin in the cells of Deiters' Nucleus, and these cells are so placed as to be under the direct control of the Cerebellum, while they are also closely related to the semi-circular canals by the Vestibular Nerve and to the Spinal Sensory paths by Collaterals furnished to them from the Spino-Cerebellar tracts. So, then, influences arriving in Deiters' Nucleus from any of these sources may be forwarded by its cells along the paths we have already noted, either upwards to the important Nuclei which regulate the position of the eyes, or downwards to the Motor Ganglion Cells of the Cord; so that Eye or Body Muscles may be ready to accommodate themselves to any changed position of the individual in space. In this place a paper by Egger^{19.} on "Ophthalmoplegie Labyrinthique" is of interest. He states that normally all changes in the position of the Head are compensated for by a corresponding change in the position of the Eyeballs; he refers the excitation of this compensatory motion to the Vestibular Nerve, and describes a case of "Tabes Bulbaire", in which the Nuclei of this nerve

being involved the eyes moved with the movements of the head instead of exhibiting a contrary motion. It is interesting to recall here the fact that almost the only sign of injury in any of the animals experimented on was Nystagmus, and that even this only occurred in certain cases. On examining the lesion in these cases it is found that this may have affected Deiters' Nucleus itself, or fallen so as to have cut the mesially directed fibres from this, or to have divided the Posterior Longitudinal Bundle above the point of entrance of these fibres; a lesion of the Posterior Longitudinal Bundle below this point producing absolutely no eye change. So that this Nystagmus is obviously to be associated with the loss of some influence derived from Deiters' Nucleus.

Bastian's^{2.} views as to the importance of the Cerebellum in relation to body movements may also be quoted here. He says: "the Cerebellum is the supreme centre for reinforcing and regulating the quantitative and qualitative distribution of outward currents in voluntary and reflex motion alike." We may, then, fairly look on Deiters' Nucleus as the distributing centre from which the cerebellar influences pass to the Cord either through the Posterior Longitudinal Bundle or by means of the

direct tract before noted; the intimate relation of Deiters' Nucleus to the Cerebellum, as pointed out by Turner, having been already described.

Tschermak, in noting the relation of the Spino-Cerebellar paths to Deiters' Nucleus, suggests that this arrangement allows of the possibility of a reflex being set up by Sensory influences ascending from the Cord to Deiters' Nucleus and reflected out along the Spinal tracts from this. In this relation it may be noted, that in some of the Cats experimented on, a slight incoordination of movement was noted, and in these cases the Posterior Longitudinal Bundle was found to have been cut below the level of the entering fibres from Deiters' Nucleus, the resulting degeneration markedly affecting the region of the Anterior Horn cells.

The share taken by the fibres taken from Deiters' Nucleus in the formation of the Posterior Longitudinal Bundle is then a very large one; indeed as regards the anterior part of this bundle, ascending fibres come almost wholly from this source, some however being added from the Sixth Nucleus. There are undoubtedly also descending fibres in this part of the Posterior Longitudinal Bundle coming from the Grey Matter in the region of the Anterior Corpora Quadrigemina; so that this portion of the bundle is certainly formed both of

ascending and descending fibres. In the lower part of its course, however, the bundle appears practically to consist of descending strands; those already noted from the Mid Brain being reinforced very largely by the indirect spinal tracts from Deiters' Nucleus. So the Posterior Longitudinal Bundle as a whole cannot be classed either as ascending (Kölliker) or descending (Gehuchten), for the direction of degenerations in this strand depends very greatly on the level at which the fibres are damaged; a lesion in the upper Medulla producing only descending degeneration, while one in the lower Pons causes marked ascending degeneration also. The great importance of the relation of Deiters' Nucleus to the fibres contained in the Posterior Longitudinal Bundle forces one to the conclusion that, as regards function, this bundle is something more than either Sensory or Motor or even Sensory-Motor, as has been suggested by various observers. It is to a large extent at least Coordinating in function putting the various nervous mechanisms of Eye and Body Muscles under the control of the cells which constitute Deiters' Nucleus, and which are in their turn subservient to the Cerebellum. The importance of the connections of this Nucleus to the semicircular canals in this relation is obvious with regard to the constant balancing of

the body and the adjustment of Eye and Body muscles in regard to this; while further influences can act on Deiters' Nucleus through its connections with the Posterior Columns of the Spinal Cord, so that the maintenance of the equilibrium of the body can be aided from this side also.

To sum up, then, the Posterior Longitudinal Bundle may be regarded as the strand through which the movement of Eye and Body muscles are associated and co-ordinated in that harmonious action which is so essential for the balancing of the individual.

Turning next to examine very briefly those changes which we have described in the Spinal Cord as produced by the lesions considered above, the general result is very similar to that originally described by Marchi ^{45.} (1891) after the removal of one Cerebellar Hemisphere, and ascribed by him to the passage into the Cord of fibres derived from this hemisphere, and running by way of the Posterior Longitudinal Bundle and the Fillet. This view of a direct cerebellar tract to the Spinal Cord has given rise to very great dispute. Marchi's view is supported by Biedl ⁶ (1895), and Thomas ⁶³ (1896) who still maintain the existence of direct descending paths in the Cord from the Cerebellum. The results obtained by English observers however are entirely

opposed to this view. Risien Russell and Ferrier and Turner have at different times and by different methods investigated these so-called Cerebellar Spinal tracts with negative results. Russell re-^{53.} moved the Cerebellum without causing more than a few scattered fibres to degenerate in the upper levels of the Cord. Ferrier and Turner^{21.} were able to analyse Marchi's degeneration into two areas and to describe a source for each, apart from the Cerebellum. The Antero-Lateral area of degeneration is ascribed by these observers to an injury of Deiters' Nucleus, the posterior to a damage to the Nucleus of the lateral Fillet.^{65.} Thomas in his most recent work on these tracts states that Russell in destroying Deiters' Nucleus probably also damaged the spinal fibres as they were leaving the Cerebellum. In this relation, the results in Monkey II are interesting, as here the lesion is a small one, well removed from the Cerebellar Peduncle, but so placed as to cut the inward passing fibres from Deiters' Nucleus; and here degeneration appears in the Antero-Lateral columns of the Cord similar to that claimed as Cerebellar in origin by Thomas. In detailing the results obtained from a series of 10 animals, Thomas states that the Cord degeneration depends not on the destruction of the Cortex of the Cerebellum, but on injury to its internal structure,

especially to the Corpus Dentatum, and admits that any injury to Deiters' Nucleus is followed by a much greater amount of degeneration. He confesses such injury is difficult to avoid; and indeed the Corpus Dentatum at its lower part approaches so close to Deiters' Nucleus that it would appear to be almost impossible to destroy the former completely without some injury to the latter. As regards, then, the source of the more anterior portion of that descending spinal tract with which Löwenthal's name is often associated, the great weight of evidence appears to be in favour of the cells of Deiters' Nucleus. The very intimate relationship of these descending Antero-Lateral fibres to the Anterior Horn cells is striking. Professor Schäfer^{56.} drew attention to these entering fibres to the Anterior Horn in a paper read before the Physiological Society in 1899. He found them degenerated after hemisection of the Cervical Cord in a Monkey. It is to be noted that the fine degeneration around these cells is specially marked in the Cervical and Lumbar regions, much less so in the Dorsal part of the Cord; so that this relationship is one of particular closeness to those cells which govern the movements of the muscles of the fore and hind limbs; and further it is noteworthy that in the Cervical Cord there is really a double association between

Deiters' Nucleus and the Anterior Horn cells through both the Posterior Longitudinal Bundle and the direct Spinal tract.

On passing to the examination of the more laterally placed degeneration in the Spinal Cord which is met with in two of the animals described above (M.III and M.VI), we find that in each case it is associated with a lesion which has spread far forwards into the Pons, even reaching the Tegmentum in the hindmost portion of the Posterior Corpora Quadrigemina in Monkey VI. In both these animals this degenerated tract occupies a very definite position lying in close relationship to the Superior Olive in the upper Pons, passing between the Sixth and Seventh Nerves in the lower part of this region, and being closely associated with the Nucleus Lateralis in the Medulla, where it lies almost in contact with the surface, slightly dorsal to the Inferior Olive. In the Cord this degeneration forms a well-marked tract, not only in the Cervical and Dorsal, but also in the Lumbar regions. It changes its position somewhat in its course downwards, coming to lie nearer the surface in the Lumbar than in the higher regions of the Cord; it does not appear to encroach on the region of the crossed pyramidal tract, being limited somewhat sharply posteriorly where the fibres of this system

lie. Other observers have noted somewhat similar degenerations. Of these the first is Bouchard^{8.} (1866) who noted that a more extensive degeneration occurred in the lateral columns after a section of the Cord itself than resulted on the removal of the opposite Cerebral Cortex. In 1885 Monakow^{48.} described, as resulting on a lesion of the Pons in a cat, the degeneration of a bundle of fibres passing between the ascending root of the Fifth Nerve and the Seventh Nerve trunk. This was traceable into the lateral columns of the Cord. In 1886 Löwenthal^{42.} describes a tract which degenerates in the Antero-Lateral columns lying somewhat scattered but mainly anterior to the crossed pyramidal tract. He notes the large size of its constituent fibres, and the fact that it does not degenerate after lesions of the Motor Cortex. He gives it the name of "Faisceau intermédiaire du cordon lateral". Marchi⁴⁵ (1891) also got degeneration in the lateral columns as the result of the removal of one Cerebellar Hemisphere. He therefore ascribes to these fibres an origin in this part. In 1894 Ferrier and Turner^{21.} noted a strand which very closely resembles the one under discussion. They found it to degenerate after an injury to the Nucleus of the lateral Fillet, and suggest for it the name of "lateral Fillet tract". The position they assign to this bundle in the Pons

and Medulla is very similar to that noted for the degenerated strand in Monkeys III and VI. In the Cord, however, they trace this no further than the Sixth Dorsal segment; while the strand noted in the above cases passes on without appreciable diminution in size into the Lumbar region of the Cord. This difference can hardly be ascribed to a failure of the method employed by these observers as Weigert's plan of staining would almost certainly have brought out a strand of this size, and their negative results make it seem probable that the two strands are not, after all, identical. Boyce⁷ (1895), after a lesion in Mid Brain, describes fibres arising in the Corpora Quadrigemina, and passing through Forel's decussation ventral to the Aqueduct, to turn downwards and to constitute, what he terms, "the lateral column tract," which is traceable on into the Spinal Cord. In the Medulla Boyce describes this strand as lying dorsal to the Nucleus Lateralis, while the position of the degeneration in Monkeys II and III is more lateral, seeming to almost surround this collection of Grey Matter. In 1898 Tschermak⁶⁸ refers to a somewhat similar tract, the origin of which he places in the cells of the Red Nucleus. Thomas⁶⁵ (1899) notes the existence of a descending strand in the lateral column of the Cord. He says that the much greater degeneration in the lateral

column, after section of the Cord than after destruction of the Motor Cortex, is due to the degeneration in the former case of a triangular strand situated anterior to the crossed pyramidal tract. He suggests the name of "Prepyramidal tract" for this.

Turning now to examine the nature of the lesion associated with degeneration of this tract in Monkeys III and VI; that in Monkey VI is very similar to the lesion described by Ferrier and Turner, the most anterior portion of the injury falling in this case in the region of the Nucleus associated with the lateral Fillet in the posterior part of the Posterior Corpora Quadrigemina. In Monkey III the lesion has not penetrated nearly so far forwards, and it would seem probable that here the lateral column tract has been injured after, not at, its origin. The exact origin of this tract then cannot be followed in the animals so far experimented on, but its distribution in the Cord, which has not been specially noted previously, comes out very well in the Cord segments prepared by Marchi's method. As the strand passes through the Medulla it is seen to furnish many fine fibres to the Nucleus Lateralis, and having reached the Cervical Cord, it proceeds to give off many fibres which enter the lateral aspect of the central Grey Matter.

These entering fibres can be traced passing from the tract right down into the Lumbar part of the Cord; they enter about the position of the so-called lateral Horn, and take a slightly forward course before breaking up into terminal branches. These ultimate ramifications are not traceable to the Anterior Horn cells, but appear to end in relation to smaller cells placed more posterior and lateral in the Grey Matter; in the Lumbar part of the Cord it is noticeable that these entering fibres avoid the cells of Clarke's column, to which the pyramidal fibres have been traced by Professor Schäfer. We have, then, evidence here of a long fibre system arising probably from cells situated in the hinder part of the Mid Brain, and passing to the Cord to end in relation to cells in the posterior portion of the Anterior Horn. What function this tract can fulfil is doubtful, but probably in some way it influences the Anterior Horn Motor Cells through the intervention of the more lateral group round which it ends, and in some way relates these to the higher centres from which it springs; in this connection if Boyce is correct in describing for these fibres an origin in the Grey Matter of the Anterior Corpora Quadrigemina, in which some of the Optic Nerve fibres have an ending, it is at least possible that a reflex path may be established by this tract

by means of which Anterior Horn cells may be (indirectly) influenced by impulses excited in the Anterior Corpora Quadrigemina by afferent messages connected with visual impressions.

The various degenerations resulting on the lesions established in this series of nine animals have now been traced to their several terminations. The great share taken by fibres from Deiters' Nucleus in the formation of the Posterior Longitudinal Bundle is, I think, fully proved; and with this the further function of co-ordinating Motor Nuclei at various levels in the Brain and Spinal Cord must be added to those already described for this tract. Indeed, this function, as judged by the number of fibres involved, would appear to quite overshadow those Sensory and Motor activities already claimed for the bundle by Held and Gehuchten. The close relationship of the descending fibres of this strand to Anterior Horn cells is well marked, and the source of those entering fibres, whose presence has been already noted by Professor Schäfer after injury to the Antero-lateral columns, can be referred, largely at least, to Deiters' Nucleus; so that a path for the co-ordinating of movements of Body muscles in response to Cerebellar, Vestibular or

Spinal influences is produced. The Nuclei of the nerves destined for the Ocular muscles are in a position to be similarly affected by impulses ascending in the fibres of Deiters' Nucleus, which take so large a share in the formation of the more mesial portion of the anterior part of the Posterior Longitudinal Bundle. That tract, whose degeneration has been traced in the lateral columns throughout the whole length of the Cord and whose termination has been noted to be in relation to the Ganglion cells of the posterior part of the Anterior Horn, is of much interest and will repay further study; the localisation of its cells of origin will probably give a further hint as to its functions, which cannot at present be definitely described.

In conclusion, I must express my indebtedness to Professor Schäfer, at whose suggestion this research was undertaken, for much kind assistance during its progress.

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